Spotted Bat (*Euderma maculatum*): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

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Author's Biography

Robert Luce, a retired wildlife biologist, was formerly employed for two years by the William D. Ruckelshaus Institute and School of Environment and Natural Resources, University of Wyoming, and two years on a sabbatical from the Wyoming Game and Fish Department to act as the Interstate Coordinator for the 12-state Prairie Dog Conservation Team. Previous to that he was employed by the Wyoming Game and Fish Department for 26 years, the last 12 of which were as the Nongame Mammal Biologist, a statewide position responsible for management of Wyoming's 84 nongame mammal species. In that position, he led the effort to conduct inventories and develop management programs for Wyoming's bat species, including the spotted bat (*Euderma maculatum*). Mr. Luce earned a Bachelor of Science in Wildlife Biology from Colorado State University in 1972.

Doug Keinath is the Zoology Program Manager for the Wyoming Natural Diversity Database, the research unit of the University of Wyoming, a member of the Natural Heritage Network. He has been researching Wyoming's wildlife for the past ten years and has 12 years experience in conducting technical and policy analyses for resource management professionals. His broader scope of research focuses on bat and small mammal ecology, survey, and monitoring at the population and landscape scales, and more recently on the spatially explicit predictive distribution modeling of sensitive animals of the Rocky Mountain West. Mr. Keinath earned a B.S. in Interdisciplinary Engineering (1993; *magna cum laude*) and a B.S. in Natural Resource Management (1993; with Distinction) from the University of Michigan and an M.S. in Wildlife Biology from the University of Wyoming (2000).

Cover Illustration Credit

Illustration of the spotted bat (*Euderma maculatum*). Illustration by Sommer Scholl of the Wyoming Natural Diversity Database; used here by permission.

Summary of Key Components for Conservation of the Spotted Bat

Virtually all agencies that are responsible for wildlife management in the United States range of the spotted bat (*Euderma maculatum*) recognize it as a species in need of special management. Regions 1, 2, and 4 of the USDA Forest Service and ten state offices of the Bureau of Land Management all list it as a sensitive species. Further, six state wildlife agencies (Arizona, California, Idaho, Montana, Utah, and Wyoming) list the spotted bat as a Species of Concern, and three states (New Mexico, Nevada, and Texas) list the species as threatened. The Western Bat Working Group lists the spotted bat as a species of High Priority for management in three of the five ecoregions in which it occurs with regularity. The Global Heritage Status Rank for this species is G4 (globally apparently secure), based primarily on the fact that abundance, population trend, and threats are not well known.

The spotted bat can be found in many western states and provinces, but its distribution is quite patchy, likely due to its dependence on large, isolated cliffs for roosting. In localities where such habitat is abundant (e.g., the Grand Canyon), spotted bats are believed to be moderately common. However, given the scarcity of suitable habitat, range-wide abundance is still thought to be fairly low. This, combined with unknown population trends, a suite of potential threats, and lack of basic life history data contribute to a broad level of conservation concern.

The main threats to the persistence of spotted bat populations are as follows:

- **Habitat alteration:** This species is vulnerable to loss or reduction in value of wet meadows and other foraging areas, at least at a local scale. Such impacts could result from over-grazing by livestock, water diversion, or changes in land use such as conversion of native habitats to tilled cropland.

- **Over-utilization:** Collection of specimens may be one of the biggest threats to this species. Because the spotted bat occurs at very low population density, loss of only a few individuals in a given area to scientific collection could be a significant population threat over a large geographic area.

- **Toxic chemicals:** Use of pesticides that bats may bioaccumulate through their diet, or that kill their prey, is a significant threat to the spotted bat. All bats are at risk from direct poisoning by insecticides due to their diet, high metabolic rates, high rate of food intake, and high rate of fat mobilization.

- **Roost loss and modification:** Although a primary threat to many bat species, the direct destruction, loss, or curtailment of roosting habitat (in this case cliffs and rock walls) does not appear to be a major range-wide threat to the spotted bat. However, roost disturbance could be locally important, for example in cases where impoundment of reservoirs, recreational rock climbing, mining, and urban or energy development may cause impacts.

Effective conservation action must simultaneously address the above-named threats if the species is to persist locally and at larger spatial scales. It is extremely important to delineate local populations and to manage this species at that scale since populations tend to be discontinuous over its range. Spotted bats can be locally common in areas with suitable habitat and an abundance of prey, but populations are often separated by large areas in which suitable combinations of roosting and foraging habitat do not exist.

The greatest conservation needs for this species are conservation of foraging habitat, roost site protection, research to develop more complete life history and ecological profiles, effective state and federal regulations to regulate take, protection from chemical exposure, development of landscape scale management strategies, including delineation of habitat criteria, and inventories to delineate current populations and distribution. These conservation issues are summarized below:

- **Habitat management:** Foraging habitat must be managed to maintain adequate insect populations. Spotted bat foraging habitat can include forest openings and subalpine mountain meadows in spruce, pine, and pinyon-juniper woodlands, large riverine/riparian areas, riparian habitat associated with small to mid-sized

4 streams in narrow canyons, wetlands, meadows, and old agricultural fields. Because habitats used for foraging can be varied, it is important to delineate ones that local populations actively use.

- **Roost protection:** The dependency on rock-faced cliff roosting habitat within 40 km of foraging areas may limit spotted bats to very small geographic areas with specific geologic features, making conservation of these areas crucial to survival of the species. Habitat on public lands is under considerable pressure from exploration and development of mineral and fossil fuel resources (including coal bed methane, oil, natural gas, and coal), recreation, timber sales, livestock grazing, and other land uses. Evaluation of these impacts on the spotted bat and its habitat during project planning is crucial. Buffers around known and potential roost sites may be essential to protect habitat and the viability of populations.

- **Life history and ecology:** The many unknowns regarding life history and the ecological needs of the spotted bat make effective management difficult. Long-term research is needed to fill gaps in knowledge.

- **Regulation of take:** State and provincial laws and regulations do not provide adequate regulatory authority and mechanisms for the protection of the spotted bat. State wildlife agency classifications are not legally binding, nor do they address habitat. For example, the spotted bat is listed in Section 11 of the Wyoming Game and Fish Commission Nongame Wildlife Regulation, a regulation that prohibits intentional take except where human health or safety concerns are involved, or under a Scientific Collection Permit issued by the Wyoming Game and Fish Department. However, the number of animals that can be taken is not restricted nor set based on scientific data, and monitoring of permits is negligible. Further, neither incidental take nor impacts to habitat are addressed. This species is not included in the Colorado Division of Wildlife's List of Endangered, Threatened and Wildlife Species of Special Concern.

- **Pesticide exposure:** Based on our limited knowledge, exposure to chemicals used in insect control projects should be minimized until impacts can be better quantified. Projects in known or suspected spotted bat habitat should be thoroughly evaluated prior to approval. Project development should include identification of roosting and foraging areas. Spray plans should be developed to avoid those areas and chemicals that avoid mortality of non-target insects should be stipulated. These actions will minimize exposure to pesticides that bats may bioaccumulate through their diet, or that kill their prey.

- **Landscape scale management:** It is imperative that spotted bat management be approached at a landscape scale, managing at the local population level while recognizing the importance of metapopulation structure to recruitment. For instance, habitat management must include protection and management of roosting and foraging areas in proximity to each other. A spotted bat may use different forest, riparian, and desert habitat types in the same area during parts of its daily or annual life cycle. Management to maintain optimal habitat within the home range of each local population will contribute to the welfare of the metapopulation.

- **Population and habitat monitoring:** To effectively manage the spotted bat, it is important to establish where the species occurs, the extent of the geographic area of occupied habitat (i.e., home range) for each sub-population, and daily movement routes between roosts and foraging areas. It is also crucial to develop monitoring strategies that establish population estimates and trends, and estimates of trends in habitat quality and quantity. Monitoring populations of species that often occur at low population densities and have large home ranges, like the spotted bat, is challenging. Further, given its unique ecology, monitoring for this species is not effectively conducted concurrently with monitoring for other bat species, thus requiring dedicated effort.

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INTRODUCTION

This Technical Conservation Assessment (TCA) was prepared for the Species Conservation Project, USDA Forest Service (USFS), Rocky Mountain Region (Region 2). It represents a complete review of the current published and unpublished (gray) literature, and includes consultation with experts in an attempt to present as much as is known concerning the distribution, biology, ecology, status, conservation, and management of the spotted bat (*Euderma maculatum*). Particular emphasis is given to Region 2, where possible. It should be recognized that there is a dearth of information for the spotted bat compared to most other bat species, so the TCA is incomplete in areas where there are no species-specific data. In some instances, the authors mention known information for other bat species, recognizing that it may or may not apply to the spotted bat.

Goal

The goal of this TCA is to provide information that the USFS and other agencies can use to develop conservation strategies and management plans for this species. The spotted bat was selected for assessment, because it is considered a sensitive species in Region 2 due to its apparent rarity, a lack of metapopulation and distribution data, and potential threats. Since there are a number of areas for which there are few biological and ecological data, the Information Needs section is a significant part of this TCA.

Scope, Uncertainty, and Limitations

Relatively little is known about the metapopulation dynamics of the spotted bat, the extent and viability of most local populations, and its seasonal movements. Life history and ecological data are mostly lacking. Systematic surveys of suitable habitat to document the presence/absence of the spotted bat have not been completed in many United States or Mexican states, or Canadian provinces, including many areas in the Region 2 states of Colorado and Wyoming.

This TCA utilizes peer-reviewed literature and unpublished (gray) literature when available, but expert opinion is heavily relied upon in instances where neither published nor gray literature exists. The knowledge of the lead author and the files of the Wyoming Game and Fish Department are the primary sources of unpublished literature and expert opinion for Wyoming, while the reviewers listed on the cover page of this TCA provided both range-wide perspective and expert opinion for Colorado.

Population and distribution information is severely lacking for this species in Region 2. This assessment is further limited by the fact that there have been relatively few long-term research projects on the spotted bat, and the small number of research projects in the published literature are local in nature and mostly from outside of Region 2. Therefore, the information and recommendations in this TCA should be viewed as a rough guide to biological and ecological parameters supporting development of conservation actions for Region 2. At the individual national forest or grassland level, site-specific habitat and presence/absence surveys should be completed, and local conservation actions and recommendations should be developed based on those findings.

Since so little information has been published on the spotted bat, this TCA departs from the format of others prepared for Region 2 and lists all published literature that mentions the species, including publications not cited in the TCA. The later are listed in the section entitled **Other References**.

Web Publication and Peer Review

To facilitate their use, these TCAs developed under USFS Region 2's Species Conservation Project are published on a dedicated World Wide Web site (http://www.fs.fed.us/r2/projects/scp). Publishing them on the Web provides more immediacy in their availability to agency biologists, managers, and the public than with more traditional forms of publication. It also facilitates the update and revision of the reports to incorporate important new information concerning these species.

In keeping with the standards of scientific publication, assessments developed for the Species Conservation Project receive external scientific peer-review as part of the publication process. Under the editorial guidance of Gary Patton (USDA Forest Service, Region 2), the Society for Conservation Biology administered the peer-review of this spotted bat conservation assessment by appropriate experts.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal Endangered Species Act

Under a classification system used prior to 1996, the U.S. Fish and Wildlife Service listed the spotted bat as a candidate species (U.S. Fish and Wildlife Service 1996). When the system was modified in 1996, the species was removed from the candidate list. Currently, the species has no status under the Endangered Species Act.

Canada

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) does not currently rank the spotted bat under the Species at Risk Act (SARA). The species is recognized and enjoys some protection under the British Columbia Wildlife Act.

Bureau of Land Management

The U.S. Bureau of Land Management (BLM) Sensitive Species Lists are developed at the state level. Ten state offices list the spotted bat as a sensitive species: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Oregon, and Wyoming.

USDA Forest Service

Regions 1, 2, and 4 of the USFS currently list the spotted bat as a sensitive species (USDA Forest Service 2005). Within the USFS, a sensitive species is a plant or animal for which population viability is a concern as evidenced by: 1) significant current or predicted downward trends in population numbers or density, and/or 2) significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

State wildlife agencies

State wildlife agency rankings for the spotted bat are shown in **Table 1**. Six states (Arizona, California, Idaho, Utah, Wyoming, and Montana) list it as a Species of Concern. Three states (New Mexico, Nevada, and Texas) list it as Threatened. Colorado classifies the species as "Non-game," and Oregon lists it as "Unclassified." States not listed in **Table 1** afford the spotted bat no special status.

Natural Heritage Network ranks

Natural Heritage ranks for the spotted bat are shown in **Table 2**. The Natural Heritage Network assigns range-wide and state-level ranks to species based on established criteria (Master et al. 2000, Keinath et al. 2003, Keinath and Beauvais 2003).

Western Bat Working Group

The Western Bat Working Group, an organization of state and federal agencies, universities, and private organizations whose goal is to bring about effective management of western bat species, developed a species priority matrix. The Western Bat Species: Regional Priority Matrix (Western Bat Working Group 1998) lists the spotted bat as a species of High Priority for management in three of the five eco-regions in which it occurs with regularity. The status of the spotted bat in each of six ecoregions is shown in **Table 3** and

Table 1. Classification of the spotted bat by state wildlife agencies; states not listed have provided no special status.

Arizona	Candidate Species – Wildlife of Special Concern List (Habitat limited and potentially threatened, population declines seem imminent)
California	Species of Special Concern
Colorado	Nongame Species
Idaho	Species of Special Concern
Montana	Species of Concern (S1 Rank = critically imperiled because of extreme rarity or biological factors that make it especially vulnerable to extinction)
New Mexico	Threatened
Oregon	Unclassified
Texas	Threatened
Utah	Species of Special Concern
Wyoming	Species of Special Concern – Native Species Status 2 (Restricted in numbers and distribution)

Table 2. Classification of the spotted bat by Natural Heritage Programs.*

- Global Heritage Status Rank: G4
- Global Heritage Status Rank Reasons: Widespread in North America; sparse, but more common than formerly believed. Abundance, population trend, and threats are essentially unknown.
- National Heritage Status Rank, United States: N3N4
- National Heritage Status Rank, Canada: N3
- U.S. and Canada State/Province Ranks: AZ (S1S2), CA (S2S3), CO (S2), ID (S2), MT (S1), Navaho Nation (S3), NV (S1S2), NM (S3), OR (S1), TX (S2), UT (S2S3), WA (S3), WY (S1B, SZN), BC (S3)

*Heritage ranks are are based on biological information on population status, natural history, and threats and are defined as follows: 1 (critically imperiled), 2 (imperiled), 3 (rare), 4 (apparently secure), 5 (demonstrably secure). -B and -N designations refer to breeding and non-breeding populations, respectively, and are generally used for species whose conservation concerns vary with season (e.g., migratory animals). State ranks are assigned based on the assessed risk of extinction within a state, while global ranks are assigned based one the species range-wide risk of extinction.

Table 3. Status of the spotted bat by ecoregions (Western Bat Working Group 1998).

- Region 1 – Peripheral (Marine Regime Mountains -western Washington and Oregon)
- Region 2 – High Priority (Intermountain Semi-Desert Province (parts of eastern Washington and Oregon, Idaho, Montana, Wyoming, Colorado, Nevada and Utah) Region 2 contains the known range in Wyoming: the inter-mountain basins adjoining the Bighorn Basin, south to the Laramie Plains, and the basins of southwestern Wyoming up to the lower elevations of the Wind River and Salt River Ranges.
- Regions 3, 4, 9, and 10 – Moderate Priority (Temperate Steppe Regime Mountains, Temperate Desert Regime Mountains, Temperate Steppe, Tropical/Subtropical Steppe (parts of Colorado, Idaho, Utah, and Texas)
- Region 5 – High Priority (Mediterranean - California)
- Region 6 – High Priority (Inter-mountain Semi-Desert - parts of Colorado, Utah, Nevada and California)
- Regions 7 and 8 – Moderate Priority (Colorado Plateau/Arizona-New Mexico Mountains - Semi-Desert parts of Arizona, New Mexico, Utah, and Colorado)

Figure 1. **Figure 1** was devised as a management tool for state and federal agencies and includes both known and potential ranges. Therefore, it does not strictly correspond with the current North American distribution (range) map for this species (**Figure 2**), which is based on documented observations.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are no management plans or conservation strategies specifically for the spotted bat in any state or province. The Western Bat Working Group developed Species Accounts for all bats that occur in the western states in 1998. From that limited summary, they agreed to develop Conservation Strategies for two species: Townsend's big-eared bat (*Corynorhinus townsendii*) and the spotted bat. The Idaho Conservation Effort published the Townsend's big-eared bat Species Conservation Assessment and Conservation Strategy in 1999 (Pierson et al. 1999). However, a spotted bat conservation assessment was never completed, and the Western Bat Working Group is not currently considering undertaking one for this species.

Most state wildlife agencies in the range of the spotted bat have completed bat conservation plans that address management needs for all bat species. Nevada completed a plan in 2002 (Altenbach et al. 2002), Arizona in 2003 (Hinman and Snow 2003), South Dakota in 2004 (South Dakota Bat Working Group 2004), Colorado in 2004 (Ellison et al. 2004), and Wyoming in 2005 (Hester and Grenier 2005). Utah and Washington are currently developing plans. These plans vary in their level of detail and strength of management recommendations, but all recognize the need for species-specific management of spotted bats. USFS Region 2 will be primarily concerned with plans in Colorado and Wyoming, the only states in the Region known to be occupied by spotted bats.

The spotted bat (**Figure 3**) is unique among bat species in Region 2 in that it apparently does not depend heavily upon caves, abandoned mines, or buildings for roosting. Therefore, conservation strategies and

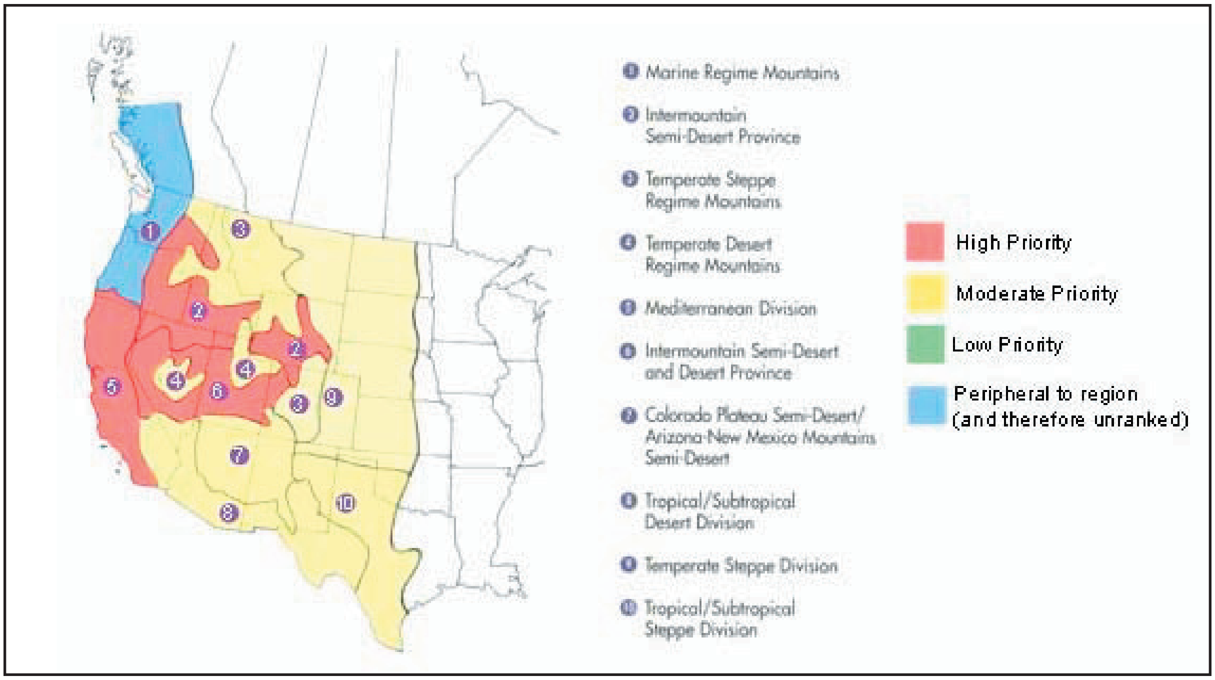

Figure 1. Regional Conservation Priority matrix for the spotted bat (Western Bat Working Group 1998).

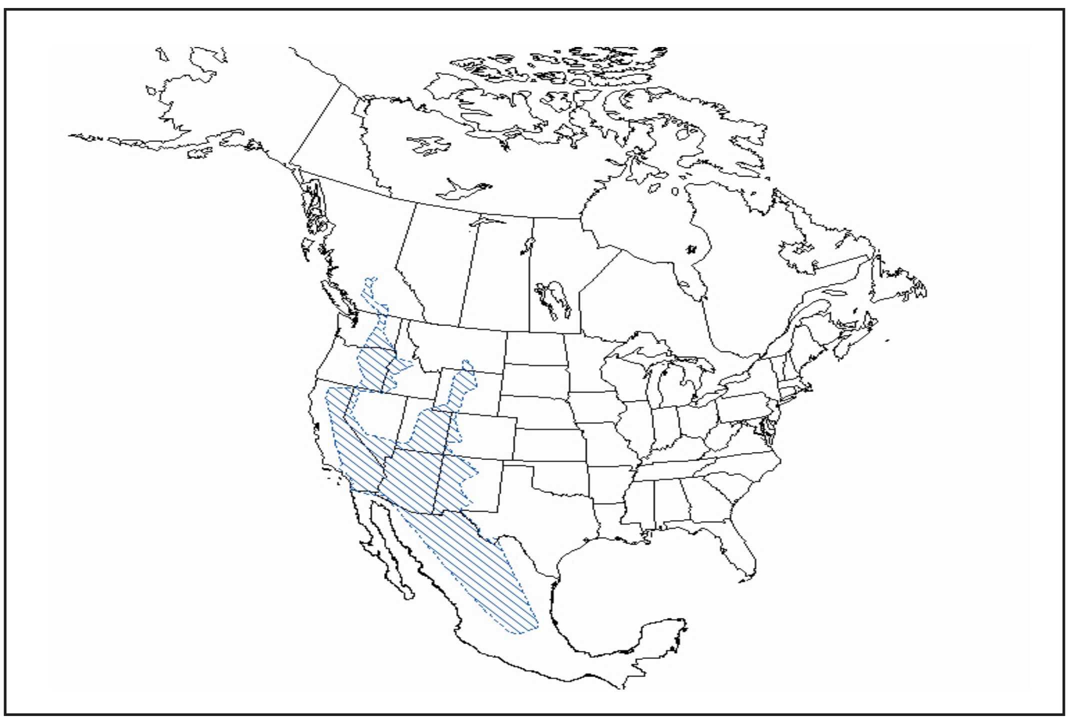

Figure 2. North American Distribution of the spotted bat.

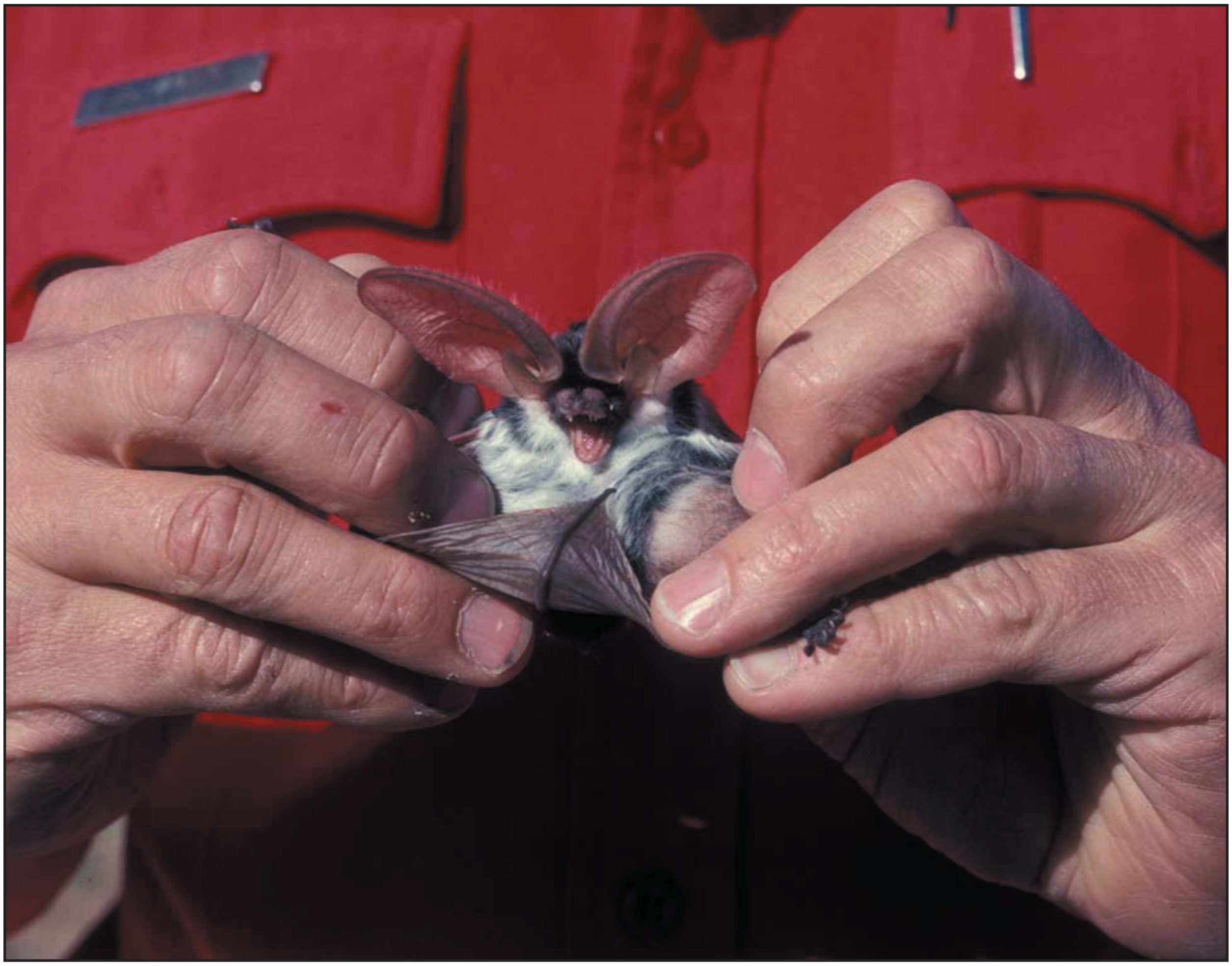

Figure 3. Photograph of the first spotted bat captured in Wyoming in 1990. Photograph by Mike Bogan. Used with permision.

recommendations to protect roosting habitat for these other species will not necessarily benefit the spotted bat. Fortunately, impacts to roosting habitat, often the primary issue for other bats, are not currently thought to be the most significant conservation concern for this species. However, similar to other bat species in Region 2, loss of foraging habitat and sub-optimal management of habitat are of critical concern.

The authors reviewed all state bat conservation plans in the range of the spotted bat during preparation of this TCA. Recommendations from several plans, especially Wyoming and Colorado, have been incorporated. It is important to re-emphasize a point made earlier in this document: state sensitive species classifications and management plans, and federal classification short of Endangered Species Act listing, provide little or no legal protection. State bat management plans provide guidance for surveys, monitoring, and habitat management, but due to rabies concerns neither their bat conservation plans nor Nongame Regulations provide direct protection for individual bats. Likewise, habitat management and protection guidelines are often general in nature.

Spotted bat habitat occurs on private and federal lands, suggesting the need for strong federal agency participation in bat conservation and management. On federal lands, management strategies to conserve and improve habitat for spotted bats will only be effective if properly reconciled with and integrated into current land, grazing, and timber management policies and on-ground management. The Wyoming BLM recently published a Spotted Bat Species Assessment (Luce 2004). Management strategies for spotted bats on BLM public lands are included in that document, and implementation will take place through individual BLM Land Use Plans.

Biology and Ecology

Taxonomy

The spotted bat is of the Order Chiroptera, Sub-order Microchiroptera, Family Vespertilionidae, Subfamily Vespertilioninae, and Group (Tribe) Plecotini (Williams et al. 1970, Frost and Timm 1992). *Euderma* is comprised of a single species, known only from western North America (Watkins 1977). No subspecies are currently recognized (Handley 1959, Best 1988). According to Williams et al. (1970), the karyotype of the spotted bat is most similar to that of the long-eared bat (*Plecotus phyllotis*), and the two are probably derived from the same ancestral stock.

According to Handley (1959), the first description of the species was in 1891: *Histiotus maculatus* J. A. Allen, Bull. Amer. Mus. Nat. Hist., 3:195, February 20, type from near Piru, Ventura Co., California. According to Miller (1897:49) in Watkins (1977), this was "probably at mouth of Castaic Creek, Santa Clara Valley, 8 mi. E of Piru Los Angeles County, California." Handley (1959) identified the first use of the current taxonomic name several years later (*Euderma maculatum* H. Allen, 1894:61; Watkins 1977).

Frost and Timm (1992) evaluated morphological and karyological characteristics and recommended that the spotted bat and Allen's big-eared bat (*Idionycteris phyllotis*) be considered sister species within the genus *Euderma*. Other research (Tumlison and Douglas 1992, Bogdanowicz et al. 1998, Hoofer and Van Den Bussche 2001) supported distinction at the genus level between the two species. The two genera remain separate at the current time.

Best (1988) examined morphological variation of 67 specimens (36 males, 25 females, and six of undetermined sex) collected from diverse habitats throughout the range and grouped into northern, southern, central, and western populations. Five external characters were recorded from specimen tags, and length of forearm and nine cranial measurements were taken from the specimens. Character heterogeneity between sexes and among the four populations was tested using one-way analysis of variance. Of 16 characters examined, 15 exhibited considerable overlap between sexes and only one character exhibited a statistically significant difference. Females were larger in length of forearm, but there was considerable overlap between sexes. Best (1988) speculated that because of the large geographic area and diverse habitats included in the analysis, sexual dimorphism may have been masked by inter-population variation or habitat characteristics. Ten of 16 characters exhibited geographic variation, similar to documentation by Best in other groups of mammals. Williams and Findley (1979) reported that females averaged over 4 percent larger than males.

Identification

The spotted bat is one of the most distinctly colored bats in the United States, and it certainly is the most distinctive of Region 2 bats. No North American bat has a similar coloration and pelage pattern, making identification generally unmistakable. The body is black dorsally, with a white spot on each shoulder and a large white spot at the base of the tail. The ventral coloration is black with white-tipped hair, giving it a white appearance. Grinnell (1910 in Watkins 1977) noted that the "death's-head" ventral pattern is unique among bats. The author speculated that it may be an adaptive function to remain inconspicuous, since the pattern is also found in moths and crepuscular birds such as poorwills and nighthawks. Only one Old World bat in the Genus *Glauconycteris* has a roughly similar appearance (Zeveloff 1988). Sexes are similar in pelage while altricial young lack the distinctive pelage pattern at birth (Easterla and Easterla 1974).

Membranes of wings and tail are thin and pliable, pinkish-red in living specimens, and gray in preserved specimens (Easterla 1965). The nose lacks large glandular masses, and the nostrils are small, similar to other vespertilionids. Easterla (1971) described a bare, non-glandular throat patch about 10 mm in diameter and hidden by fur unless the head is tipped back. Poche (1981) discussed the potential for this patch to act as a heat exchange mechanism during high roost temperatures. The auricle and tragus are large; the tragus lacks a basal lobe and is united with the posterior basal lobe of the auricle. The pinkish, hairless ears are 45 to 50 mm in length with a simple tragus. The ears are erect in active individuals, but in a state of rest or torpor are folded and curled back against the body in a "ram's horn" position (**Figure 3**). With a total length of 107 to 115 mm, forearm 48 to 51 mm, tail 47 to 50 mm, and length of ear 45 to 50 mm (Watkins 1977), this species is one of the larger vespertilionid bats in Region 2. Tables of measurements for specimens examined can be found in Handley (1959).

The voice of the spotted bat is best described as a soft, high-pitched metallic squeak or a chirp. It occasionally clicks its teeth together and makes a grinding noise (Handley 1959). Like several other bat species, the spotted bat is known to emit clicking or ticking sounds prior to taking flight (Easterla 1965).

The spotted bat and big free-tailed bat (*Nyctinomops macrotis*) are the only two bat species in Region 2 that emit an echolocation call audible to the human ear. Two other Region 2 bat species, the pallid bat (*Antrozous pallidus*) and the Mexican free-tailed bat (*Tadarida brasiliensis*), have vocalizations that are audible to the unaided human ear (Priday and Luce 1999). Calls of these bats are only made at roosts and in-flight to avoid collisions with other bats. Although both species vocalize, they do not use audible calls consistently and not at all for locating prey (echolocation). Therefore, calls are distinct from those of the spotted bat.

The spotted bat and the pallid bat are by far the most common of the four species mentioned above based on current data (Priday and Luce 1999, K. Navo personal communication 2005). Only one record of a big free-tailed bat exists for Wyoming (Bogan and Cryan 2000), and there are 13 confirmed records for Colorado (K. Navo personal communication 2005). Three records for the Mexican free-tailed bat exist for Wyoming (Priday and Luce 1998, Bogan and Cryan 2000), while a large number exists for Colorado (K. Navo personal communication 2005).

Current opinion is that both big free-tailed and Mexican free-tailed bats are more widespread and occur further north than has been previously documented (K. Navo personal communication 2005). K. Navo (personal communication 2005) believes that the big free-tailed bat is widespread in Colorado, is found as far north as northwestern Colorado (outside of the current known range), and is more common in Wyoming than current data indicate. Big free-tailed bats move into Colorado in significant numbers in the fall, which may mean they are migrating from areas further north (Navo et al 1992, K. Navo personal communication 2005), including Wyoming. Audible surveys for spotted bats in both Wyoming and Colorado should take into account the possible presence of big free-tailed bats and take care to separate the two species.

Range

In 1959, the spotted bat was thought to occur from northwestern Mexico to southern Canada (Hall and Kelson 1959). The range map for the species did not change significantly in a more recent revision of the known distribution (Hall 1981). At that time, scattered records indicated a range from Durango, Mexico to British Columbia (Watkins 1977, Woodsworth et al. 1981).

Currently, the spotted bat is known to be distributed across large areas of western North America from southern British Columbia to the central Mexican state of Queretaro (Easterla 1970, Schmidly and Martin 1973, Watkins 1977, Leonard and Fenton 1983, Navo et al. 1992, Perry et al. 1997, Pierson and Rainey 1998). **Figure 2** depicts current understanding of this species' range.

Range extensions for the spotted bat reported over the last 30 years include Big Bend National Park in Texas (Easterla 1973), northwestern Colorado (Finley and Creasy 1982, Navo et al. 1992, Storz 1995), Oregon (McMahon et al. 1981, Barss and Forbes 1984, Rodhouse et al. 2005), southern Utah (Poche and Bailie 1974, Poche 1975, Ruffner et al. 1979, Poche 1981), southern British Columbia (Woodsworth et al. 1981), northern California (Bleich and Pauli 1988, Pierson and Rainey 1998), New Mexico (Perry et al. 1997), Wyoming (Priday and Luce 1999), and Utah (Toone 1991, Storz 1995).

In Region 2 states specifically, before 1990 the known range in Wyoming was confined to the Bighorn Basin in north-central Wyoming based on two historical records: a single specimen found dead near Byron in the northern Bighorn Basin (Mickey 1961) and a photograph of a spotted bat taken in a building in the same general area (Priday and Luce 1999, Bogan and Cryan 2000). The first captures in Wyoming were two live specimens taken in mist nets from the same general area on Little Mountain Plateau in August 1990 (Priday and Luce 1999). More recently, Keinath (2005) recorded echolocation calls of free-flying specimens in Bighorn Canyon.

Of 34 records (11 locations) reported by Priday and Luce (1999), seven are from the Bighorn Basin, one from Sweetwater County near the northern end of Flaming Gorge Reservoir in southwestern Wyoming, one from near Boysen Reservoir in Fremont County (west-central Wyoming), and two from Johnson County (northeastern Wyoming). With the exception of the Sweetwater County record, all observations were made incidentally during mist net surveys at or near caves and abandoned mines. None of the 34 observations were part of a systematic survey for spotted bats. Therefore, the current range map for Wyoming in Priday and Luce (1998, 1999) probably under-represents the true range of the species for the state. For example, low elevation public lands adjoining the southern end of Wyoming's Bridger-Teton National Forest and containing juniper or sagebrush habitats are suitable habitat for spotted bats. These areas should be considered potential habitat, since they were not adequately surveyed by Garber (1991) or during other survey efforts.

Several blocks of spotted bat habitat in Wyoming have been systematically surveyed without documenting occurrence and can reasonably be excluded from the state distribution map. Surveys conducted in 1997 at 12 low elevation (1460 to 2750 m) sites on the Shoshone National Forest resulted in no audible calls recorded (Priday and Laurion 1998). Garber (1991) listened for audible calls, mist netted, and used a QMC Mini-2 Bat Detector at 30 sample sites on the Bridger-Teton National Forest and 22 sample sites on Targhee National Forest in 1991 without detection of spotted bats. The sample sites ranged from 1840 to 3035 m elevation. Garber (1991) opined that the majority of these two national forests are above the upper elevational limit for the spotted bat and so are not occupied, except perhaps peripherally.

In Colorado, spotted bats have been captured in Dinosaur National Monument at Brown's Park in extreme northwestern Colorado, and at two other places in western Colorado; one of the captured individuals was a lactating female (K. Navo personal communication 2005). The Colorado Division of Wildlife documented presence of spotted bats from skulls found in spotted owl (*Strix occidentalis*) pellets at Mesa Verde National Park near Cortez (extreme southwestern Colorado) and from captures in west-central Colorado south of Grand Junction (Paradox Valley) (K. Navo personal communication 2005). Although a systematic survey effort has not been conducted for spotted bats in Colorado, most suitable habitat has been evaluated for its potential except perhaps in the southeastern part of the state (K. Navo personal communication 2005).

The spotted bat is not known from South Dakota (Herren and Luce 1997, Luce and Herren 1998, Higgins et al. 2000, Schmidt 2002), and occurrence in Nebraska and Kansas is unlikely (e.g., Jones et al. 1985). These data also indicate a low probability that eastern parts of Colorado and Wyoming are inhabited.

Abundance

In the past, the spotted bat has been considered a rare species (Snow 1974, Watkins 1977). From 1891, when the species was first described, until 1965 only 35 specimens were reported in the scientific literature (Watkins 1977). An additional 18 specimens were reported between 1965 and 1977 (Watkins 1977). However, more recent data are changing that perception, revealing that the species may be comparatively abundant in some locales while rare in others. Easterla (1973) found it locally abundant at sites in Texas, and Rabe et al. (1998) found it locally common north of Grand Canyon National Park in Arizona. Data from British Columbia also suggest local abundance (Woodsworth et al. 1981, Leonard and Fenton 1983). Navo et al. (1992) found spotted bats locally common, though not abundant, in Dinosaur National Monument in northwestern Colorado.

Fenton et al. (1983) sampled for spotted bats in 80 areas within the expected geographical range of the species, documenting presence in 10. Spotted bats were detected at 34 of 142 sites (24 percent) sampled within the 10 areas in which the species was known to be present. Fenton et al. (1983) believed capture records to be a reliable indicator of abundance for this species, a hypothesis supported by Berna (1990). Conducting general bat surveys along the Kaibab Plateau in Arizona in August 1988, Berna (1990) captured eight bats, three of which (38 percent) were spotted bats. Likewise, Doering and Keller (1998) documented spotted bats at five of 11 (45 percent) of their sample sites in the Bruneau-Jarbidge River area of southwestern Idaho. Findley and Jones (1965) sampled ponderosa pine (*Pinus ponderosa*) forests in New Mexico in 1961 and 1962. Of 107 bats captured, seven (7 percent) were spotted bats. Toone (1991) documented this species at 50 of 60 (83 percent) sample sites in the Abajo Mountains in southeastern Utah.

Conversely, Worthington (1991) captured 1,101 bats at five caves and four water sources in the Pryor Mountains of Montana. Even though Worthington observed spotted bats throughout the southern portion of Bighorn Canyon National Recreation Area, including southern Montana and northern Wyoming, of the 1,101 bats taken only two (<1 percent) were spotted bats. Similarly, Kuenzi et al. (1999) captured 299 bats of 11 species during a study in west-central Nevada, but only three (1 percent) were spotted bats.

This species probably occurs naturally in highly localized sub-populations where suitable habitat conditions exist, leaving large areas unoccupied. For instance, Rodhouse et al. (2005) confirmed multiple individuals at five locations, but no more than three individuals at any one site in Oregon. However, as noted previously, systematic surveys for the spotted bat have not been undertaken in parts of its range, leaving large gaps in our understanding of its distribution and abundance. Because the spotted bat is often not effectively sampled during general bat surveys, especially during mist net surveys at the entrances of caves and abandoned mines or over ponds, past studies have typically underestimated both distribution and abundance of the species. Consequently, data do not exist to compare current and historic abundance, and comprehensive surveys targeting spotted bats are required to erase those knowledge gaps. Emphasis on this species during survey efforts in Colorado and Wyoming by federal and state agencies could significantly improve our knowledge of its distribution and abundance in Region 2.

Population trend

Since this species is rarely captured during general bat surveys and acoustic and Anabat® surveys have been only recently used to record local distribution, regional, range-wide, and statewide trend data are not available. Likewise, little anecdotal information exists. In Region 2, follow-up surveys have not been conducted at locations in Colorado and Wyoming where the spotted bat has been documented in the past. Consequently, no information exists on persistence and changes in abundance over time.

Activity and movement patterns

Seasonal movements

Seasonal movement of this species is not well understood or documented, but like other bat species the spotted bat either hibernates in winter or moves to lower elevation and/or latitude where some combination of hibernation and winter feeding activity can be supported. There are no data to document spotted bats wintering in Region 2, but hibernation somewhere within the summer-fall range is assumed. Conditions in Wyoming and Colorado from November through March are not conducive to bat activity due to the ambient cold temperatures and lack of insect prey.

M.B. Fenton (personal communication in Toone 1991) opines that it is unknown whether the species migrates locally, hibernates, or is a long distance migrant, but some support for seasonal movement exists. Berna (1990) observed spotted bats at higher elevations in conifer forests in early summer and then at lower elevations later in the summer, suggesting altitudinal migration. Poche (1981) observed spotted bats primarily in low elevation xeric areas, but suggested they may wander to higher elevations to escape summer heat. Rodhouse et al. (2005) believed that the disappearance of two male spotted bats fitted with radio transmitters late in August provided evidence of transience in Oregon. They suggested these bats may travel considerable distances between summer roosts and winter hibernacula. In Nevada, Geluso (2000) noted that the cities of Reno and Las Vegas account for 35 percent (n = 11) of spotted bat records in the state, and that eight of the 11 bats documented were found in late August and early September. He suggested this may indicate that the spotted bat wanders to lower elevations after bearing and raising its young. The Nevada Bat Conservation Plan (Nevada Bat Working Group 2002) stated this species hibernates in Nevada but does not address the seasonal movement issue.

In a New Mexico study, the spotted bat was documented in a ponderosa pine forest only during the period June 23 to July 1, leading to speculation that specimens taken elsewhere in August and October may indicate post-breeding wandering (Handley 1959). Barbour and Davis (1969) suggested that this species is a resident of the ponderosa pine zone in June and July and wanders to lower elevations in autumn. Findley and Jones (1965) similarly concluded that the spotted bat bears and rears young in ponderosa pine forest and perhaps other forest types in the Southwest, moving to lower elevation winter range after the breeding season. Likewise, Hoffmeister (1986) reported spotted bats at low elevation sites near Yuma in April and at higher elevations near St. George, Utah and the Arizona/Utah state-line in December and January. There is no evidence that spotted bats congregate at, or move to, maternity sites.

Racey (1982) speculated that high-energy demands on lactating female bats in July and August probably force them to choose the most productive foraging habitat. Rabe et al. (1998) found spotted bats in meadows in ponderosa pine habitat along the rim of the Grand Canyon in the early evening in July and August, suggesting that the bats were roosting in the canyon and traveling to foraging areas above the rim. The large elevation and temperature difference between the hot, low elevation desert cliff roosting sites and the high, cool subalpine meadow foraging sites presented bats an opportunity to forage in several habitat types and possibly allowing them to choose the most productive habitats on a daily or seasonal basis. They did not capture spotted bats at this site during any other season of the year, indicating a seasonal shift likely occurs in the Grand Canyon area.

Winter records of spotted bats from southwestern Utah (Hardy 1941) and in New Mexico, Utah, and California (Sherwin and Gannon 2005) are all from areas where this species also occurs in spring, summer, and fall, indicating that at least some individual bats did not move far between their summer range and wintering area. Hardy (1941) also reported at least four hibernating spotted bats near Kanab, Utah, where this species also occurs during spring, summer, and fall. Ruffner et al. (1979) sampled over a desert wash in southwestern Utah at elevation 823 m during November 1974 through March 1975, documenting winter activity for spotted bats in January and February. Free water and insects were available all winter, leading them to suspect year-round presence of the bats. Following up on that research, Negus (personal communication in Hoffmeister 1986) reported mist-netting spotted bats in November and June in the same area as Ruffner et al. (1979), confirming that the species is present in the area all year and not as a result of seasonal movement. The coldest temperature Poche (1981) captured spotted bats in southwestern Utah was –5 degrees C, and he speculated that this species may emerge from torpor to obtain water. As in the study by Negus, Poche's (1981) study site occasionally warms enough during the winter to stimulate insect emergence and providing foraging opportunities for bats. These studies suggest that areas where temperatures do not drop below approximately –5 degrees C could support at least some bat activity year-round. However, Poche (1981) winter-surveyed 17 caverns and caves near Ft. Pierce Wash, a well-documented spotted bat use area in spring, summer, and fall. While he found several bat species, no spotted bats were located and suggesting they had moved out of the area.

There are no winter records for spotted bats in Wyoming or Colorado. Winter surveys of 161 caves and 137 abandoned mines in Wyoming between 1994 and 1997 documented no use by this species (Priday and Luce 1998). The spotted bat was not documented during a 14-year survey period of over 2,000 abandoned mines in Colorado. The Wyoming and Colorado data suggest either seasonal migration or a hibernation strategy other than use of hypogeal roost sites. Insects are unlikely to be active for a significant period at any outside location in Wyoming or Colorado during the winter.

Daily activity

In early studies, Barbour and Davis (1969) and Easterla (1965) speculated that the spotted bat is a late flyer similar to Townsend's big-eared bat. Barbour and Davis (1969) documented most captures after midnight and noted only one conflicting record in Constantine (1961), who reported one capture at 2038 h.

The preponderance of data does not support the hypothesis that the spotted bat only forages or flies late at night. Rodhouse et al. (2005) observed this species flying within 38 minutes after sunset on the Crooked River, and they first heard calls 43 minutes after sunset in Dry River Canyon (both locations in central Oregon). They also observed spotted bats near dawn on several occasions, including one observation 78 minutes before sunrise. Mead and Mikesic (2001) documented emergence from a cave roost in Arizona 15 to 30 minutes after sundown, and spotted bat activity all night. Peak activity was from 2100 h to midnight and from 0400 to 0500 h. Rabe et al. (1998) first detected spotted bats at 2010 to 2030 h (2.8 h to 3.2 h after sunset) in northern Arizona and believed these times represented emergence from the roost. They also documented arrival of a female spotted bat at a foraging site at 2130 h, foraging until 2400 or 0100 h, night roosting between 0330 and 0350 h, and then returning directly to a day roost on a cliff. Winter captures of seven spotted bats in Utah were between 2.5 and 11 hours after sunset, again indicating activity over the entire night (Ruffner et al. 1979). Poche and Bailie (1974) reported captures at 2215 and 2230 h.

Priday and Luce (1999) reported spotted bat activity from 10 sites in Wyoming. The earliest nightly activity was at 1900 h on October 16, 1995, 2112 h in July, and 2030 h in August. During August sampling, foraging activity was documented several times between 2030 to 2330 h in a meadow in the vicinity of a spring pond. Spotted bats in Dinosaur National Monument first arrived at foraging areas at 2123 h (+/-11 m) and remained active throughout the night (Storz 1995). Using a bat detector and audible call recognition, Navo et al. (1992) documented both early evening appearance of spotted bats and all night activity in northern Colorado. Wai-Ping and Fenton (1989) and Leonard and Fenton (1983) found spotted bats active throughout the night in southern British Columbia, with peak foraging activity from 0000 to 0300 h (50 percent of the nightly activity).

Recent research indicates that activity peaks reported in early literature are likely artifacts of the proximity of sampling sites to diurnal roosts and/or drinking sites (Storz 1995). At eight of 15 sample locations, Storz (1995) documented only commuting spotted bats with a fairly constant number of passes per night, indicating movement to and from roost sites to foraging areas. Spotted bats foraged within the study site for 6.22 m (+/-2.4 m) out of every 15 m sampling period between 2100 and 0400 h. Foraging sessions only lasted 5.48 m (+/-2.74 m) (Storz 1995).

Habitat

The spotted bat probably uses similar habitats from spring through at least early fall, although males and females may not use the same areas. The key resources required by all bat species are roosts, forage, and water. Early records appeared to indicate a preference for forested habitat (Vorhies 1935) or caves (Vorhies 1935, Hardy 1941, Parker 1952). Since then, the spotted bat has been reported from a wide variety of habitats from desert shrub to coniferous forest (Findley and Jones 1965).

Ruffner et al. (1979) captured six males at Ft. Pierce Wash 13 km southeast of St. George, Utah, in June in riparian habitat consisting of creosote bush (*Larrea tridentate*), mesquite (*Prosopis glandulosa*), tamarisk (*Tamarix chinensis*), desert willow (*Chilopsis linearis*), baccharis (*Baccharis glutinosa*), and arrowweed (*Pluchea sericea*). Hoffmeister (1986) reported a male spotted bat captured in a ravine along the lower Colorado River in creosote-dominated habitat in June, and a specimen (unknown sex) taken in the summer in the city of Tempe in the Salt River Valley where habitat was historically creosote-dominated Sonoran Desert, but is now irrigated agriculture or urban area. Kuenzi et al (1999) captured spotted bats June through August in Great Basin desert shrub (sagebrush [*Artemisia* spp.], saltbush [*Atriplex* spp.], pinyon pine [*Pinus monophylla*], and juniper [*Juniperus osteosperma*]). Rodhouse et al (2005) found spotted bats far from large bodies of water in dry upland habitat in central Oregon.

By contrast, Rabe et al. (1998) found spotted bats in subalpine meadows in July and August on the Kaibab National Forest in Arizona. Associated forest species included ponderosa pine, Douglas-fir (*Pseudotsuga menziezii*), white fir (*Abies concolor*), and patches of aspen (*Populus tremuloides*). The July temperature at this elevation averaged 23 degrees C. One spotted bat was radio-tracked to its day roost at an elevation of about 700 m on a south-facing limestone cliff about 150 m above and 200 m from the Colorado River. The site was Sonoran Desert habitat with predominantly catclaw (*Acacia greggii*) and mesquite. Average July temperature was 35 degrees C at the closest weather station to the roost site, Phantom Ranch in Grand Canyon National Park at 748 m elevation. After foraging in the subalpine meadows previously described, the female roosted for several nights in the same patch of aspen on the south face of a small ridge, 1 km east of the meadow. Pierson and Rainey (1998) confirmed spotted bats in black oak (*Quercus velutina*), ponderosa pine, incense cedar (*Calocedrus decurrens*), giant sequoia (*Sequoiadendron giganteum*) /red fir (*Abies magnifica*), lodgepole pine (*Pinus contorta*), and white fir habitats in California.

Williams (2001) sampling from June through January, found spotted bats in Nevada using mesquite bosques up to 5 m tall consisting of native screwbean mesquite (*Prosopis pubescens*) and honey mesquite (*P. glandulosa*). These areas were recovering floodplains where agriculture and grazing had ceased. Riparian marshes near the headwaters of the river were the second most commonly used habitat. These were dominated by mixed sedges (*Carex*, *Eleocharis*, *Juncus*), cattail (*Typha*), and graminoids to 0.5 m in height. Riparian shrubland habitats were used to a lesser extent and consisted of monotypic stands of arrowweed (*Pluchea sericea*) and quailbush (*Atriplex lentiformis*) as tall as 2 m.

Pierson and Rainey (1998) and Wai-Ping and Fenton (1989) never observed spotted bats more than 10 km from substantial cliff features regardless of habitat type during studies in California and British Columbia. Rocky cliffs (**Figure 4**) have been recognized as preferred roosting habitat in several other studies (Easterla 1970, Watkins 1977, Ruffner et al.1979, Leonard and Fenton 1983). Wai-Ping and Fenton (1989) radio-tracked four females, including one lactating female, to roosting sites on cliff faces in British Columbia.

On several occasions in Utah, Poche and Baillie (1974), Poche (1975), and Poche and Ruffner (1975) observed released spotted bats landing on and crawling over rock faces on steep-walled canyons, seeking and entering crevices in or under rocks.

In Wyoming, spotted bat occurrence was documented at nine sites (**Table 4**). Site #2, Spring Creek Canyon, is a 4.8 km-long canyon with sheer limestone cliffs and a small perennial stream running through stands of boxelder (*Acer negundo*), with mountain mahogany (*Cercocarpus montanus*), big sagebrush (*Artemisia tridentata*), and juniper on the slopes between the stream and the canyon rim. Site #3, Canyon Creek, is also a perennial stream in a canyon of rugged rock outcrops and steep canyon walls, with juniper (*Juniperus scopulorum*) and big sagebrush. Site #4, elevation 1890 m, is approximately 0.8 km from the Green River in a rugged canyon with bare rock walls containing numerous cracks and fissures, greasewood

Figure 4. Typical spotted bat habitat in Region 2 consisting of a concentration of large cliffs proximate to open water and extensive foraging areas. See text for a complete description of habitat preferences (Bighorn River in Sheep Canyon north of Greybull, Wyoming; photograph by Bob Luce).

Table 4. Spotted bat habitat associations in Wyoming and Colorado.

Wyoming	
Site #2:	Spring Creek Canyon: boxelder trees near the stream; mountain mahogany, big sagebrush, and juniper above the stream to the canyon rim.
Site #3:	Canyon Creek: steep canyon walls with juniper and big sagebrush.
Site #4:	Green River: greasewood at base of cliffs, big sagebrush on plateau.
Site #5:	Steep canyon: Douglas-fir interspersed with limber pine and aspen.
Site #6:	Wind River Canyon: many limestone karst caves, big sagebrush and juniper along the river, sagebrush-grassland habitat on adjacent plateaus.
Site #7:	Sheep Canyon: rock walls, mixed sagebrush-grassland on the plateau.
Site #8:	Middle Fork Powder River: Narrowleaf cottonwood and boxelder near the stream; lodgepole pine, juniper, and big sagebrush on bench between river and canyon walls. Adjacent plateaus dominated by sagebrush-grassland with scattered lodgepole pine.
Site #9:	Mixed lodgepole pine and Douglas-fir interspersed with sagebrush-grassland parks.
Site #10:	Boysen Reservoir: Rock bluffs in sagebrush-grassland.
Colorado	
Site #1:	Echo Park, Dinosaur National Monument: meadow.
Site #2:	Small pond in sagebrush/pinion juniper habitat surrounded by cliffs.
Site #3:	Dolores River: small pond in a mixed agriculture/desert shrub habitat surrounded by sheer rock cliffs.

(*Sarcobatus vermiculatus*) on slopes above the canyon bottom, and big sagebrush on the plateau. Site #5 in Park County, northwestern Wyoming, elevation 1920 m, is a steep-walled canyon, with Douglas-fir interspersed with limber pine (*Pinus flexilis*) and aspen.

Site #6 is in Wind River Canyon, an area of limestone karst with several natural caves and bare rock walls. Big sagebrush and juniper occur along the river, with sagebrush-grassland on the adjacent plateaus. Site #7 in Sheep Canyon along the Bighorn River has sheer rock walls immediately adjacent to the river, with mixed sagebrush-grassland on the plateau. Site #8 on the Middle Fork of the Powder River at elevation 1597 m is a karst area with bare rock walls of limestone. Vegetation along the river included narrowleaf cottonwood (*Populus augustifolia*) and boxelder, with lodgepole pine, juniper, and big sagebrush between the river and the canyon walls. Adjacent plateaus are dominated by sagebrush-grassland with scattered lodgepole pine. Site #9 is in a karst area near Mayoworth at elevation 2530 m. The site is located in an area of mixed lodgepole pine and Douglas-fir interspersed with sagebrush-grassland parks. Rock outcrops and a canyon with bare rock walls occurs within 1.6 km of the site, and three man-made stock ponds occur within 3.2 km. Site #10 is on the shore of Boysen Reservoir near several high rock bluffs in sagebrush-grassland at 1460 m elevation.

All four captures of spotted bat in western Colorado were in limestone canyon/cliffs: one over a meadow in Echo Park, Dinosaur National Monument; two at a small pond in sagebrush/pinion juniper habitat surrounded by cliffs; and one at a small pond in a mixed agriculture/desert shrub habitat surrounded by sheer rock cliffs near the Dolores River (**Table 4**; K. Navo personal communication 2005).

Foraging habitat

Spotted bat foraging activity has been reported in subalpine mountain meadows (Rabe et al. 1998), forest openings (Woodsworth et al. 1981), pinyon juniper woodlands, low upland slopes of juniper and sagebrush, along the rims of cliffs, riverine/riparian habitat along rivers (Navo et al. 1992), riparian habitat associated with small to mid-sized streams in narrow canyons (Priday and Luce 1999), wetlands, meadows, and old agricultural fields (Leonard and Fenton 1983, Wai-Ping and Fenton 1989, Worthington 1991, Pierson and Rainey 1998, Rodhouse et al. 2005). Foraging often takes place near or over water, similar to other bat species (Waldien and Hayes 2001). This is likely a function of prey availability rather than habitat type.

Leonard and Fenton (1983) found that spotted bats preferred foraging in open areas associated with ponderosa pine forest in June, July, and August. They also documented use of old fields consisting of knapweed (*Centaurea* spp.), with bunchgrass (*Agropyron* spp.) in moist depressions and ponderosa pine along the field margins. Irrigated hay fields planted to alfalfa (*Medicago sativa*) and bordered by ponderosa pine were also used. Woodsworth et al., (1981) observed spotted bats along the Okanagan River in southern British Columbia in May, June, and August at elevations ranging from 500 to 1500 m in habitat dominated by sagebrush (*Artemisia* spp.), low grasses, and open ponderosa pine forest. The habitat is described as more typical of semiarid habitats much further south. Leonard and Fenton (1983) observed spotted bats using burned-over ponderosa pine forest, but not foraging there.

Wai-Ping and Fenton (1989) observed spotted bats foraging in open areas 6 to 10 km from day roosts in cliffs. Foraging took place in a variety of habitats, but mostly over marshes and in open ponderosa pine woodland where foraging bats could fly 5 to 15 m above the ground in large elliptical paths with long axes of 200 to 300 m. Perry et al. (1997) captured lactating females foraging over a stock pond in open grazed meadows surrounded by mixed conifer forest 0.4 km from cliffs in the Sacramento Mountains of New Mexico.

In Colorado, Storz (1995) documented spotted bats at Echo Park Meadow (1548 m) and Pool Creek (1635 m) foraging in open meadows with dominant ground cover of cheatgrass (*Anisantha tectorum*), various bunchgrasses, and isolated boxelder stands. Echo Park is adjacent to the Green River and sandstone cliffs. The spotted bat was also documented at Orchid Draw and Red Wash, which are dry desert washes characterized by rabbitbrush (*Chrysothamnus nauseosus*), sagebrush (*Seriphidium tridenta*), greasewood (*Sarcobatus vermiculatus*), and shadscale (*Atriplex confertifolia*).

Priday and Luce (1999) reported the capture of two lactating female spotted bats foraging and watering at a small spring pond on August 27 and 28 in open juniper (*Juniperus scopulorum*) grasslands on Little Mountain Plateau in extreme northern Wyoming. All of their spotted bat observations in late summer and early fall were associated with habitats containing canyons with cracks and fissures; high, bare rock walls; and rock ridges close to permanent water. Warm season occurrence of spotted bats in Wyoming may be more closely associated with habitat structure and roost availability in proximity to foraging areas than specific vegetation types (Priday and Luce 1999).

Elevation

The spotted bat has been documented from 57 m below sea level (Grinnell 1910 in Watkins 1977) to the high transition zone of the mountains in Yosemite National Park, California (Ashcraft 1932 in Watkins 1977). Recent surveys in California (Pierson and Rainey 1998) documented several localities above 2000 m, the highest of which was 2926 m in Deadman Canyon, Sequoia National Park. Distribution in Nevada is between 540 and 2130 m (Nevada Bat Working Group 2002). A record from the summit of Mount Taylor in New Mexico at 3230 m (Reynolds 1981) is the highest elevation occurrence documented.

In Colorado, Storz (1995) documented spotted bats at Echo Park Meadow (1548 m) and Pool Creek (1635 m) in Colorado, while K. Navo (personal communication 2005) reported audible records from 3 higher-elevation sites in the western portion of the state (3024 m, 2438 m, and 2347 m). Priday and Luce (1998) documented this species at 1890 m in southwestern Wyoming, 1920 m in northwestern Wyoming, and 2530 m in central Wyoming. Twelve sites surveyed for spotted bats on the Shoshone National Forest in Wyoming contained suitable habitat, but at 1460 to 2750 m, eight of the sites were higher than the highest elevation at which the spotted bat has been documented in Wyoming. Researchers speculated that some element of elevation may have been a limiting factor in this area (Priday and Laurion 1998).

On the other end of the scale, Ruffner et al. (1979) reported capturing seven spotted bats (three females and four males) in January and February at Ft. Pierce Wash near St. George, Utah at an elevation of 880 m. Several stock tanks and the Virgin River are within a 10 km radius of the site. Rabe et al. (1998) found a female roost at an elevation of about 700 m on a south-facing limestone cliff about 150 m above the Colorado River in Arizona. The lowest elevation documented for spotted bats in southern British Columbia is along the Okanagan River at 500 to 1500 m (Woodsworth et al.1981, Van Zyll de Jong 1985).

Water resources

Water loss in bats is high due to the respiratory demands of flight (Studier and O'Farrell 1980). Therefore, in arid regions, surface water for drinking may be a limiting factor for all bat species (Cross 1986). Numerous researchers have documented heavy use of natural and manmade water sources (Chung-MacCoubrey 1996, Cockrum et al. 1996, Szewczak et al. 1998), either for drinking or foraging. The spotted bat has been observed watering at small ponds less than 20 m in diameter in northern Wyoming, echolocating and apparently watering over ponds greater than 20 m in diameter in southwestern Wyoming, and echolocating and presumably watering over a large reservoir in central Wyoming. The larger ponds were near a large reservoir (R. Luce, personal observation).

Roosts

Sherwin and Gannon (2005) reported published anecdotal accounts for 24 spotted bat roost locations. Four observations were in the winter (between November 1 and April 30): two in buildings in Albuquerque, New Mexico, one in a cave in Utah, and one at the base of a cliff in California. Thirteen summer roosts were in human-made structures: four on cliffs, two in caves, and one in a tree stand. Mead and Mikesic (2001) estimated between six and nine individuals day-roosted in a cave in northern Arizona from May 6 to early October, and they captured 11 individuals (nine adult males, two adult females) on August 16-17.

While the spotted bat had been reported in caves or cave-like situations (Vorhies 1935, Hardy 1941, Parker 1952, Priday and Luce 1999), until recently use of such sites other than incidentally during any season of the year had not been documented. However, the cave roosts noted above, along with the fact that 15 of 24 roosts (63 percent) reported by Sherwin and Gannon (2005) were in human-made structures, roost types not previously considered important for this species, may be significant in terms of management.

Area requirements and landscape context

The spatial relationship between roosting and foraging habitat is especially important for the spotted bat, whose distribution is limited by the occurrence of suitable roosting and foraging habitat within travel distance of each other. As previously noted, rocky cliffs near forest foraging sites have been recognized as preferred habitat in a number of studies (Easterla 1970, Watkins 1977, Ruffner et al. 1979, Leonard and Fenton 1983), so a mixture of habitat types at the landscape scale may be necessary. For instance, Rabe et al. (1998) found female spotted bats foraging in meadow systems for part of the night, night roosting in trees bordering the meadows, and day roosting in cliffs.

A summary of telemetry field studies presented by Kunz and Pierson (in Nowak 1994) showed great variability in travel distances for foraging bats due to extrinsic factors such as local topography, water sources, landscape mosaic, and prey distribution and abundance. Minimal data exist on home range requirements for this species; daily movement patterns and distance may be the best indicators of home range. Bats travel no farther than necessary from roost to foraging area, but changes in areas used are likely based on forage availability and season. Rabe et al. (1998) noted a female spotted bat making a daily one-way flight of 38.5 km and a male making a one-way flight of 32 km. These distances appear to indicate very large home ranges compared to those observed by Wai-Ping and Fenton (1989) where bats foraged only 6 to 10 km from day roosts.

Food habits

Diet

Spotted bats feed primarily on flying moths (Easterla 1965, Ross 1967). Ross (196l, 1967) and Easterla and Whitaker (1972) found that stomach contents and fecal pellets indicated that 97 to 100 percent of prey items were moths (probably noctuids) ranging in size from 5 to 11 mm. On the Kaibab Plateau in Arizona in 2002, Painter (2003) also found spotted bats feeding primarily on moths (Noctuidae, Lasiocampidae, Geometridae), and additionally noted some consumption of beetles (Coleoperta; <2 percent of digested material). Although the spotted bat has been reported to pursue grasshoppers (Poche and Bailie 1974) and other insects (Findley 1987) on the ground, Leonard and Fenton (1983) discount these later reports as instances in which they have followed a typanate moth towards or onto the ground after the moth detected the bat's echolocation call.

Foraging strategies

The spotted bat is not restricted to particular vegetation associations (Wai-Ping and Fenton 1989, Navo et al. 1992). Therefore, structural features of the habitat related to density or clutter may be the biggest determining factors concerning habitat suitability and use of foraging space (Storz 1995). Woodsworth et al. (1981) describe the spotted bat as a high-flying, fast foraging bat emitting a low frequency echolocation call of 8 to 15 kHz, with maximum energy at 10.9 kHz. They observed one spotted bat return to the same site, a 1 to 2 ha clearing in ponderosa pine forest, at the same time of night (2100 h) on four subsequent nights. The bat always entered the clearing from the uphill side, made several circuits of the clearing for 3 to 5 min at a height of 10 to 15 m and within 20 m of the forest edge, and then left the clearing on the downhill side. Another spotted bat observed for five consecutive nights used a "trapline" foraging strategy, where it searched at least six clearings in ponderosa pine forest within an 8 km^2 area. The bat always arrived at the first clearing about 20 minutes after dark and at each of the other clearings within 3 minutes of arrival on previous nights.

Storz (1995) documented spotted bats arriving after dark at foraging sites in Echo Park Meadow, Dinosaur National Monument, at 2123 h +/-11 min MDT, and remaining active throughout the night. Eighty-one and one-half percent of foraging activity occurred over open meadows, which constituted about 85 percent of the site, while 18.5 percent of activity occurred at mid- to upper-canopy level within 8 m of leafed boxelders. Spotted bats circled closely above and around individual trees or isolated clumps of trees, but they were rarely observed closer than 0.5 m of the canopy, and no instances of hovering or foliage gleaning were noted. They foraged at the study site for 6.22 +/- 2.40 min out of every 15 min sampling period between 2100 and 0400 h. At Pool Creek, foraging spotted bats typically flew in large circular or elliptical orbits at heights of 10 to 30 m above the ground. Although canopies of boxelder and cottonwood comprised a larger percentage of this study site, all activity occurred over open meadows (Storz 1995). Foraging sessions lasted 5.48 +/- 2.74 min, and foraging took place for 6.82 +/- 5.03 min out of every 15 min sampling period between 2100 and 0200 h. Leonard and Fenton (1983) similarly observed spotted bats flying in elliptical orbits 10 m above the ground, 40 to 70 m in length, and 20 to 30 m in width from May through July. The feeding pattern was less predictable later in the summer and in the fall, with bats foraging over larger areas and spending less time at any one site.

Rabe et al. (1998) documented the arrival of a female spotted bat at a foraging site at 2130 h, foraging until 2400 h or 0100 h, night roosting between 0330 and 0350 h, and returning directly to the day roost on a cliff. Other female spotted bats with radio transmitters foraged in specific meadow systems for part of the night, night roosted in trees bordering meadows for about 3 h, and abruptly departed for day roosts between 0300 and 0400 h. Woodsworth et al. (1981) observed up to nine spotted bat passes during a 15-minute period as they flew from an area of high cliffs at dusk toward foraging areas in ponderosa pine forests. Wai-Ping and Fenton (1989) observed this species foraging in open areas only 6 to 10 km from day roosts in cliffs and flying about 19 km per h while foraging. Rabe et al. (1998) speculated that the long foraging distances they observed may be explained by a lack of suitable high-cliff roost sites near referred foraging sites in the meadow systems on the Kaibab National Forest, while the abundance of large (>10 mm) moths justified the energy expenditure of such long flights.

Foraging patterns appear similar throughout the range, but Painter (2003) speculated that where they are active during winter months, spotted bats might feed on insects that exhibit more enriched isotope signatures than those she found in the summer on her study area in subalpine meadows on the Kaibab Plateau. Seasonal foraging patterns may shift.

Leonard and Fenton (1983, 1984) estimated that spotted bats in British Columbia maintained a distance of at least 50 m from other adjoining foraging spotted bats through mutual avoidance, actively monitoring proximity to conspecifics using the same area. Woodsworth et al. (1981) observed two spotted bats encountering each other and maintaining about 100 m distance from each other. Storz (1995) observed similar behavior in Dinosaur National Monument. Foraging spotted bats produced agonistic vocalizations when a 50 m buffer zone was breached by another spotted bat. These vocalizations were different than feeding buzzes and occurred only during close encounters between conspecifics. Of 247 feeding buzzes, there was never more than one per minute from the same bat.

The spotted bat may have a unique echolocation strategy in that its calls are apparently not detected by moths until the bat is less than 1 m away (Fullard and Dawson 1997). This provides a substantial advantage over species such as the little brown bat (*Myotis lucifugus*), which can be detected by some moths at over 40 m (Woodsworth et al. 1981), or the big brown bat (*Eptesicus fuscus*), which is detected at 20 to 25 m (Fullard and Dawson 1997). Apparently the spotted bat attacks prey at a rate much lower than is typical of bats in general (Barclay 1985, Hickey and Fenton 1990). Woodsworth et al. (1981) observed only six feeding buzzes during 44 minutes of observation of a single spotted bat. During 37 foraging sessions, spotted bats attacked an insect every 2.15 minutes on average (0.466+/-0.294 attacks per minute; range 0.16 – 0.94; n = 152 feeding buzzes).

Water

The spotted bat drinks on the fly by skimming the surface of open water sources such as ponds, spring ponds, lakes, and tanks. This bat needs a short swoop zone in order to water on the fly and is one of several species that can use a water source such as a cattle stock tank (Herder 1998). Like most bats, the spotted bat probably waters shortly after emerging from its day roost and before evening foraging begins. There is some evidence that desert bats, especially species that forage over wet meadows such as the spotted bat, may receive some of their water requirements from their prey (Brown and Berry 2000).

Breeding biology

Reproduction in spotted bats is not well understood, but there is no evidence that females congregate into maternity colonies (Poche 1975) like other bat species in Region 2. The breeding season may vary with locale. While early evidence indicated breeding from late February to April, with young born in May or June, more recent evidence demonstrates a protracted or variable period of breeding.

Easterla (1965, 1973) caught a male spotted bat with enlarged testes in Texas during late summer and speculated that this may indicate copulation in the fall, with parturition during the spring after delayed implantation, similar to other vespertilionids. Navo (personal communication 2005) also captured a male spotted bat with enlarged testes in August in Colorado. Poche (1981) found mature spermatozoa in one individual caught in the spring, indicating spring/summer breeding, and other recent studies have indicated summer breeding as well (i.e., juvenile males were captured in mid-August in Colorado; K. Navo personal communication 2005).

Easterla (1965) captured two pregnant females in early June in Texas, and Poche (1981) captured a pregnant female about to give birth in Utah near the Utah-Arizona state line on June 20. Lactating females have been captured in late June and early July in New Mexico, mid-July in Wyoming and Colorado, and mid-August in Utah (Jones 1961, Easterla 1965, Barbour and Davis 1969, Easterla 1979). Hence, the indication is strong that parturition occurs prior to mid-June

(Watkins 1977) in at least some areas. Post-partum females have been captured June 23 and July 1 in New Mexico (Jones 1961), June 30 in New Mexico (Findley and Jones 1965), August 10-18 in Utah (Easterla 1965), August 3-9 in Texas (Easterla 1970), August 27-29 in northern Wyoming (Priday and Luce 1999), and in late August in Colorado (K. Navo, personal communication 2005). These data indicate early- to mid-summer breeding in Region 2.

Population demography

Spatial characteristics and genetic concerns

The published literature gives no data on metapopulation dynamics for the spotted bat. Small, scattered populations appear to be the norm for this species. No data exist on potential inbreeding.

Life history parameters

Very little is known about the population demographics of the spotted bat. What we do know suggests that it is a relatively long-lived species with a low reproductive rate. Spotted bats apparently give birth to one altricial young per litter (Easterla 1965, Findley and Jones 1965, Easterla 1971). No data exist on neonate mortality or adult and juvenile survivorship.

To explore possible demographic options, we used largely hypothetical data to construct a matrix life-cycle model for the spotted bat (**Appendix**). The authors present this model as a preliminary attempt to investigate demographics for this species, recognizing that due to significant data gaps the model will require considerable revision in the future as more data become available. Modeling results suggest that spotted bat population growth (λ) is more sensitive to changes in first-year survival than to changes in other rates, and it appeared to show little sensitivity to changes in fertility. Overall, adult survival transitions accounted for approximately 88 percent of the total elasticity of λ to changes in the vital rates (see **Appendix** for definition of terms). Further, introduction of stochasticity to the model suggested that populations of spotted bats are relatively tolerant of stochastic fluctuations in offspring production (e.g., missing a litter due, for example, to annual climatic change or to human disturbance), but they are extremely vulnerable to variations in the survival of adult stages. This suggests that in the absence of unforeseen external factors, enhancement of post-weaning survival is the key to spotted bat population viability.

Community ecology

The primary factors influencing occurrence of spotted bats at the subpopulation level appear to be either habitat or food-related. Cliffs or rock walls must be associated with meadow foraging habitats, and moths present in foraging areas must be of a particular size and type (Ross 196l, 1967, Easterla and Whitaker 1972, Painter 2003). Easterla and Whitaker (1972) examined stomach contents and fecal pellets and found that 97 to 100 percent of prey items were moths (probably noctuids) ranging in size from 5 to 11 mm. While this may have been a function of availability, it may also indicate a narrow range of acceptable prey and could be severely limiting for these bats. Structural features of habitat related to density of clutter may be predictive of habitat suitability and use of foraging space (Storz 1995), limiting spotted bats to only those areas meeting structural criteria. Mead and Mikesic (2001) suggest that spotted bats were unable to roost/live as far north as the Grand Canyon until summer temperatures and rainfall patterns had established the modern regime (ca. 11,000 to 10,200 years B.P.). This suggestion was based on a fossil specimen they dated at ca. 10,500 years B.P. and may indicate that temperature and rainfall still place some limits on distribution of this species on a range-wide scale.

Predators and competitors

From the few data available, the spotted bat apparently suffers from low predation rates. American kestrel (*Falco sparverius*), peregrine falcon (*F. peregrines*), and red-tailed hawk (*Buteo jamaicensis*) have been observed diving at released, banded spotted bats (Easterla 1973). Black (1976) reported one instance of a kestrel capturing a spotted bat. Owls may occasionally take bats, but predation by raptors is probably rare. Due to the unique roosting and foraging strategies of the spotted bat, competition from other bat species or insectivorous birds does not appear to be a survival factor.

Parasites and disease

Whitaker and Easterla (1975) reported the external parasites *Cryptonyssus* spp., *Basilia rondanii* spp. and *Ornithodorus* spp. on spotted bats from west Texas, and *B. forcipata* from spotted bats in New Mexico. Poche and Keirans (1975) reported a larval tick, *Ornithodoros rossi* on a spotted bat in Utah. No internal parasites have been reported (Watkins 1977).

The spotted bat is susceptible to rabies, and under some conditions this disease could impact local populations (Medeiros and Heckmann 1971, Constantine 1979). However, the solitary nature of the species limits opportunities for exposure and potential for passing the disease.

Symbiotic and mutualistic interactions

Because the spotted bat seldom roosts in association with other bat species, there are no known symbiotic or mutualistic interactions. Spotted bats drink on the fly over ponds and streams, so a theoretical commensal relationship could exist with beaver (*Castor canadensis*), which form ponds of quiet water suitable for drinking.

Envirogram

Andrewartha and Birch (1984) propose a "Theory of Environment" that attempts to chart the ecology of a species into a web of factors that influence survival and reproduction. The envirogram is used to organize these factors into a hierarchical dendrogram. The "centrum" is the list of components that act directly on the species, and branches form links to distal elements in the "centrum." The envirogram developed for the spotted bat (**Figure 5**) is an attempt to model the environment of this species, but the authors recognize that many elements may be missing from the model given the complexity of such an effort and the many ecological factors that are unknown.

CONSERVATION

Extrinsic Threats

The spotted bat is undoubtedly rare and perhaps always has been; therefore, recent decline cannot be assumed. Potential threats common to other rare wildlife species, such as genetic factors and natural predation, are not known to be significant for this species. Either individually or additively, the following are potential threats to the spotted bat: disturbance, scientific collection, habitat alteration, chemicals, wind energy development, and disease.

Disturbance

Several researchers (Easterla 1973, Poche and Bailie 1974, Poche 1975, 1981) documented lack of mark/recapture returns for spotted bats, suggesting that the species is sensitive to even minimal human disturbance and may abandon an area due to human activities. Most bat species are especially sensitive to disturbance at roosts, particularly roosts in caves, abandoned mines, and buildings. The spotted bat, however, apparently endures little impact from human disturbance at its remote cliff-face roost sites, a situation that will probably continue for the foreseeable future over most of its range. Still, impoundment of reservoirs and recreational rock climbing can severely impact the species locally (Snow 1974, Pierson and Rainey 1998). Because Sherwin and Gannon (2005) recently found that the species uses building roosts more commonly than previously thought, disturbance or other impacts to building roosts could be an ongoing threat not previously recognized as important in this species.

Scientific collection

The rarity of the spotted bat makes it a sought-after museum specimen. Rarity also makes collection a potentially significantly impact on local populations (O'Farrell 1981, Fenton et al. 1987).

Habitat alteration

Oil reserve pits associated with oil drilling operations can be a source of bat mortality (Flickinger and Bunck 1987), because bats can often mistake them for natural water sources. Various species of bats have drowned in these ponds in Wyoming (Esmoil and Anderson 1995, B. Weynand personal communication 1995). Although mortality of spotted bats at these ponds has not yet been documented, there is potential for such mortality to occur.

Livestock grazing has been responsible for large-scale conversion of mesic riparian habitats to xeric uplands throughout the West. Overgrazing can also increase invasive weed growth, reducing the quantity and quality of native vegetation in riparian zones. Reduction in prey availability may then result from reduced diversity of insect-supporting plant species (South Dakota Bat Working Group 2004). Although the impact of reduced prey availability on the foraging strategies of the spotted bat has not been documented, the species prefers noctuid moths that are obligates of lentic vascular hydrophytes such as *Thya*, *Salix*, *Pontederia*, and *Polygonum* (Lange 1979). Consequently, any reduction or elimination of these host plants by livestock and livestock grazing could affect the local noctuid prey base of spotted bats.

Conversion of wetlands, wet meadows, or spring overflow areas to xeric sites by draining these sites, lowering the water table, or overgrazing by livestock,

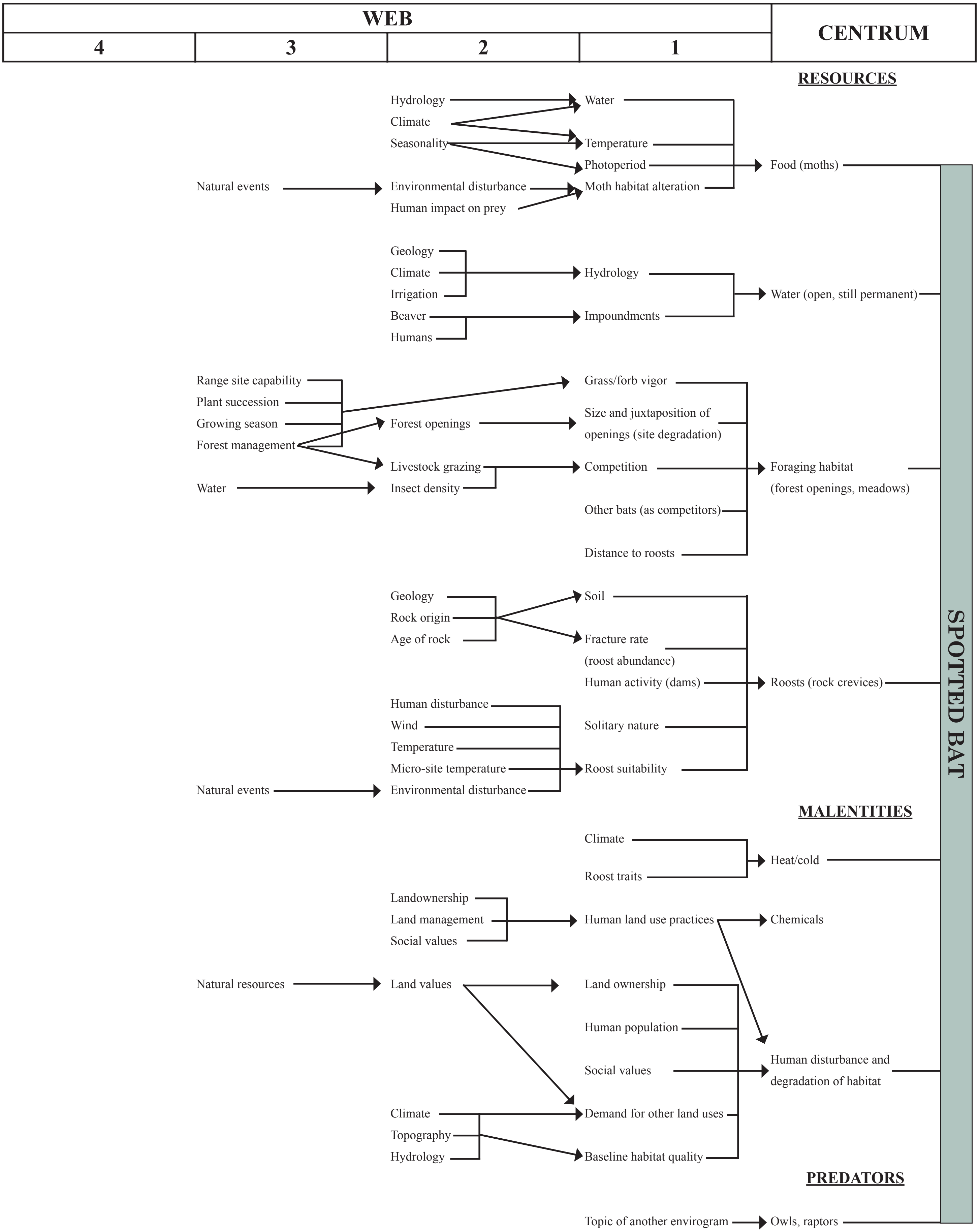

Figure 5. Envirogram of the ecological web surrounding the spotted bat. Detailed explanation of envirograms can be found in Andrewartha and Birch (1984).

all of which reduce the amount of clean, open water, is a significant threat to all bat species. Likewise, conversion of wet meadows or wetlands to tilled cropland, and invasion of sedge and grass meadows by shrubs or trees through dewatering, seeding, or over-grazing, have the potential to adversely impact spotted bats.

Timber harvest in riparian areas will impact all bat species to a degree. Total bat activity averaged 4.1 to 7.7 times higher in wooded areas than in adjacent logged areas in western Oregon, and more lepidopterans, a primary forage species for the spotted bat, were captured in wooded habitat than in logged areas (Hayes and Adam 1995). Spotted bats prefer forested cover interspersed with small openings, and alteration of this condition by creating large openings during vegetation or timber management activities could substantially diminish habitat quality by reducing the amount of edge and contributing to habitat fragmentation (Ekman and de Jong 1996). Bat foraging habitat is enhanced by retaining natural, pre-harvest variability in stand structure, including the interspersion of openings with natural variability in size and shape (Walker et al. 1995). Insect occurrence and density depend on adequate quantity, quality, proportions, configurations, and distribution of wet meadows and insect-supporting terrestrial vegetation, such as grasses and sedges in meadows and forest openings.

Chemicals

Large-scale, non-target pesticide spraying activities could adversely impact spotted bats through secondary poisoning of bats and reduction of their prey base. Rainey and Pierson (1996) believe the potential exists for chemical pollutants to cause bat declines in local areas. The extent of impacts to local populations of spotted bats are unknown due to lack of research data in the area of chemical impact on bats and none specific to this species.

Clark (1988) suggested that bats are at risk from direct poisoning by insecticides due to their diet, high metabolic rates, high rates of food intake, and high rates of fat mobilization. Clark and Stone (2001) compared levels of contaminants in tissue of birds and bats and found a much higher concentration in juvenile gray bats (*Myotis griescens*) than in red-winged blackbirds (*Agelaius phoeniceus*) in the same study area. Fenton et al. (1983) stated that accumulation of pesticides through consumption of insects and direct loss of prey base are two of the biggest threats to the spotted bat.

Keinath (2004) provided an excellent discussion of the general impacts of pesticides on bats, including some of the reasons why bats may exhibit an elevated rate of bioaccumulation of environmental contaminants. These reasons include:

- ❖ high metabolic demands associated with small body size and flight demand
- ❖ pronounced fat cycles due to migration and hibernation demands
- ❖ concentration of chemicals in milk, potentially reducing fecundity
- ❖ coincidence of bat evening feeding regimes with application of pesticides during that time period to minimize drift
- ❖ long life spans in bats allowing greater time for accumulation of contaminants
- ❖ increasing bat exposure to toxicants due to the communal roosting exhibited by bats, especially in buildings treated with wood preservatives such as lindane and dieldrin.

Clark and Shore (2001) summarized mean lethal concentrations of some chemicals in the brain of bat species. However, their results were entirely based on laboratory investigations are data are lacking for bats in the wild. They suggested that sublethal doses may impact bats by reducing coordination, preventing flight and, therefore, foraging, thereby resulting in death. Bats with diminished capacity may be more susceptible to their predators. None of these causes of death would routinely be attributed to chemical exposure without a dedicated investigation, further contributing to the lack of data and understanding of chemical impacts on bat populations.

Non-target insecticide sprays reduce the number of insects available to foraging bats (Brown and Berry 1991) and have been identified as a factor contributing to the decline of bat populations in North America (Clark 1981). Non-target lepidopteran sprays used to control gypsy moth outbreaks may reduce local moth populations for several years, and even *Bacillus thuringiensis* sprays may suppress tussock and spruce budworm moths enough to impact bats (Perkins and Schommer 1991). The insecticide diflubenzuron (Dimilin) is an insect growth regulator that may produce significant indirect impacts on bats by reducing the food available (Sample and Whitmore 1993). Malathion and carbaryl are insecticides that may also impact bats and are widely used for large-scale range and agricultural spraying projects over thousands of acres, including controlling Mormon cricket populations in Wyoming.

Chemicals used in heap-leach gold mining may be a significant threat to bats. Cyanide leach ponds are known to have resulted in poisoning of bats (Clark 1991, Ellison et al. 2004). A threat exists to bats using the ponds as a watering source, and insects emerging from contaminated sediments of lakes and reservoirs may carry elevated levels of toxicants that can be transferred to bats that consume them (Steingraeber et al. 1994, Clark and Shore 2001). Clark and Shore (2001) found PCB's, lead, cadmium, and blue-green algal toxins in effluent from cyanide extraction gold mines and impounded sewage.

Wind energy development

Wind-energy turbines have the potential to impact bats due to mortality from collision with turbine blades (Osborn et al. 1998, Keeley et al. 2001, Johnson et al. 2003). Mortality of several bat species at wind turbines has been documented, primarily red bats (*Lasiurus borealis*) and hoary bats (*L. cinereus*), but also eastern pipistrelles (*Pipistrellus subflavus*), little brown bats, silver-haired bats (*Lasionycteris noctivagans*), and big brown bats. There are currently no reports of spotted bats impacted by wind turbines.

Disease

Bat rabies is endemic in North America, but it primarily affects *Eptesicus*, *Myotis*, *Tadarida*, and *Lasiurus* species and occurs at a very low rate of prevalence even in those species (Rupprecht 1990). While the spotted bat is susceptible to rabies, there is no evidence that the disease impacts the species to a significant degree. The spotted bat was not represented in the sample of 1,100 specimens turned in to the Wyoming State Veterinary Lab for rabies examination between 1981 and 1992 (Priday and Luce 1998, Bogan and Cryan 2000).

Biological Conservation Status

Abundance and abundance trends

The spotted bat has long been considered rare throughout its range (Snow 1974, Watkins 1977), but recent data are changing that perception somewhat (Priday and Luce 1999, Nevada Bat Working Group 2002, Rodhouse et al. 2005). Some biologists believe that the species is not as rare as was previously thought, and while not widespread, it is locally abundant in areas with suitable habitat (K. Navo personal communication 2005). Likewise, the Western Bat Working Group believes that the spotted bat is more widespread than was thought a decade ago (L. Lewis personal communication 2005). Reasons why this species has been overlooked during bat surveys in the past appear to be largely tied to the ineffectiveness of standard survey techniques in detecting spotted bats. For example, Rodhouse et al. (2005) captured this species only with intense effort using alternative capture methods, such as elevated mist nets. They believed that spotted bats would not have been captured during studies using standard methods and, therefore, would be erroneously declared absent from those study areas and resulting in a inaccurate estimate of occurrence and abundance for Oregon.

While most suitable habitat in western Colorado has been surveyed for the spotted bat, there have been fewer efforts to document occurrence in Wyoming. The first capture of this species in Wyoming was in August 1990 (Priday and Luce 1999). The fact that 33 additional records were documented between 1994 and 1997 indicates that it is more abundant than previously known. However, there is no reason to believe that the species is more common now than it was historically. The greater number of recent observations appears to be the result of increased reporting and survey effort, rather than an upward trend in numbers. Figures contrasting documented locations per state in a status report prepared for the U.S. Fish and Wildlife Service in 1981 (O'Farrell 1981) versus records from the recent literature are shown in **Table 5**.

Distribution trends

While survey efforts in the last decade have expanded our knowledge of distribution of the spotted bat, the limited data do not indicate any changes in distribution in Region 2 or on a range-wide scale in the last 100 years. However, data collection has not been conducted over a sufficiently long period to establish changes in distribution of the species. The spotted bat appears to remain locally common in areas with suitable habitat and abundance of prey, but populations are often separated by large areas in which suitable combinations of roosting and foraging habitat do not exist. This makes the range-wide distribution of the spotted bat highly fragmented naturally and makes it difficult to measure changes in distribution. Local populations in Wyoming

Table 5. Comparison of number of records of spotted bats known pre-1981 (O'Farrell 1981) with records known in 2003 (data do not imply trend since systematic surveys were not conducted).

	Pre-1981	2003
Arizona	6	No data
California	10	23 (Pierson and Rainey 1998)
Idaho	1	No data
Montana	1	No data
New Mexico	9	No data
Nevada	6	11 (Geluso 2000)
Oregon*	1	2 (Rodhouse et al. 2005)
Texas	3	No data
Utah	12	10 (Toone 1991)**
Wyoming	1	14 (Priday and Luce 1999)

*Not included in O'Farrell

**O'Farrell records were re-evaluated

Although spotted bats may be more abundant than previously thought, they remain distributed in scattered, localized populations, and is found in low densities relative to other bat species. Because of its patchy distribution, low densities, and narrow habitat requirements, Region 2 managers should continue to assume that this is a rare species and manage accordingly.

are geographically separated from each other during at least the spring-fall period (Priday and Luce 1999). At present, Wyoming and Colorado populations appear to be significant to maintenance of the spotted bat range-wide, both in terms of distribution and numbers.

Habitat trends

It is beyond the scope of this assessment to describe the differences between historic versus current forest habitat conditions or to extrapolate trends in habitat alteration and other impacts on bats. However, trends in land use, including that on public lands, suggest that quantity and quality of spotted bat habitat may continue to decline. Since all habitat needs must be met both at the scale of individual sub-populations and at the landscape scale, impacts due to accelerating energy development are likely occurring without our knowledge in many areas.

Exploration and development of mineral and fossil fuel resources (e.g., coal bed methane, oil, natural gas, coal) continue at high levels. Seismic surveys are expected to continue to occur over vast areas in the immediate future and could reduce spotted bat habitat values near roosts. O'Farrell (1981) considered this a threat more than 20 years ago, and the intensity of development has accelerated considerably since that time. Power plants, with their associated power lines and roads, and wind energy developments continue to invade new areas, often previously remote public lands, with the potential to reduce both roosting and foraging habitat. Impoundment of new reservoirs, which may cause permanent loss of habitat, is less of a factor than in the past. Cliff roosts are vulnerable to disturbance associated with rock climbing or other recreational activities, and those activities are on the increase. Improper livestock grazing management, timber exploitation, and hardrock mining continue to have the potential to reduce available roosting and foraging habitat for the spotted bat. However, due to a lack of data, the cumulative effects of these impacts cannot yet be quantified.

Intrinsic vulnerability

The spotted bat characteristically occurs at a low population density and in disjunct sub-populations, which have less opportunity for outside recruitment. While this reduces the vulnerability of metapopulations, these intrinsic factors dictate a high level of vulnerability for local populations. Combined with a low reproductive rate, these factors make it difficult for local sub-populations to recover following the loss of large numbers of breeding adults. Furthermore, while the species is a generalist in terms of foraging habitat, it specializes in prey selection which makes sub-populations vulnerable to loss of important foraging habitats.

Management of the Spotted Bat in Region 2

Implications and potential conservation elements

The spotted bat is identified as a priority species in the Western Bat Species: Regional Priority Matrix (Western Bat Working Group 1998), indicating that all management entities, including state wildlife agencies and federal land management agencies, should give this species priority in management planning. While there is still much to learn about the spotted bat, what is known about risks and avoidance or minimization of them should be considered whenever potential impacts to the species or its habitat are likely from private, state, or federal action. Habitat use, prey species, roosting sites, foraging areas, distances from roosting to foraging areas, and conservation needs may vary somewhat over the range. However, lack of specific state or local data should not be a deterrent to application of the management strategies presented in this assessment. The best available range-wide and regional information should be used to develop both local and regional management strategies that are refined as more data become available.

Bats utilize resources at the landscape scale. This is especially true of spotted bats, which due to natural habitat fragmentation, often must travel longer distances to meet their roosting, foraging, and watering requirements. The spotted bat, perhaps even more than other bat species, occurs in locally isolated sub-populations, found only where all habitat components including roosts, foraging areas, and water are juxtaposed effectively. Due to the arid nature of much spotted bat habitat, areas of such habitat juxtaposition can be highly disjunct. Consequently, good spotted bat management requires management at a landscape scale and in an ecosystem context. Land management must take into account the spatial arrangement of roosting, watering, and foraging areas, as well as suitable movement corridors connecting these habitats (Pierson 1998, Herder and Jackson 1999). Because of the high energy demands of foraging bats, the closer the essential habitat elements are to each other (ideally as close as 1 to 4 km; Keinath 2004), the higher the likelihood of persistence of a sub-population. In areas known to be occupied by spotted bats, it is important to understand, manage toward, and, where necessary, restore natural patterns and processes of occupied ecosystems. It may also be prudent to expend survey effort in marginal areas (those lacking only one or two habitat components or essential juxtaposition) to identify areas where it may be possible to maintain or improve conditions suitable for occupation and population expansion by spotted bats.

Continued collection and refinement of data, state and federal agency recognition of the need to manage this species, and state and federal development and implementation of effective management strategies may be major factors in precluding the need to list this species under the Endangered Species Act. The North American Bat Conservation Plan developed by Bat Conservation International and the Western Bat Working Group will provide guidance in Canada, the United States, and Mexico. State bat conservation plans should also be an important element of federal planning and management efforts.

Sound conservation efforts for spotted bats in Colorado and Wyoming depend on gathering more data on regional distribution and population ecology. The two greatest needs are inventories in suitable habitat (especially western and central Wyoming and southeastern Colorado), and routine monitoring in areas of known occurrence to establish trend. Inventories in a variety of habitats will offer further insight into habitat specificity and variability. Documentation of seasonal use of habitats, winter status, and migration are also critical information needs.

Tools and practices

Management practices

It is beyond the scope of this Species Conservation Assessment to describe all tools and practices necessary to conserve the spotted bat. However, this assessment provides a number of specific management strategies and practices, recognizing that in many instances insufficient data exist at this time to fully support them. Even though concrete data are lacking, action is clearly warranted. Therefore, the authors rely upon personal experience, expert opinion, on-going research, and, in some cases, published management recommendations for other bat species to provide the following management recommendations for the spotted bat. We recommend that the Wyoming and Colorado bat conservation plans and local experts be consulted for more locally-specific information.

Three habitat components are of primary importance to the spotted bat: roosting, watering, and foraging. The species' dependency on rock-faced cliff roosting habitat within 40 km of foraging areas may define habitat suitable to support a local subpopulation.

The following recommended practices apply to lands managed by Region 2. Through land trades, private/federal agreements, use of federal programs for private land initiatives such as those administered by the Natural Resource Conservation Service, and funding of projects by private conservation organizations on federal lands, these practices could be expanded to include private lands either adjacent to or intermingled with federal lands. These recommendations maximize bat habitat conservation and are not intended to take into account other land management issues that Region 2 managers may need to address.

- **Protection of roosting habitat:** Potential suitable roosting habitat should be identified at both local and landscape scales based on habitat descriptions and parameters presented in this TCA. Geographic Information System (GIS) technology may offer an important tool to overlay key habitat attributes that may help to identify potential habitat. Identified sites can then be ground-truthed to verify potential suitability. Where suitable habitat appears to exist, inventory methods (see this assessment) should be employed to document presence/absence of the spotted bat and to identify roost sites. Land management actions in areas occupied by, or which appear to be suitable for occupation by, spotted bats should be carefully evaluated for their implications to populations and habitat.

  Altenbach et al. (2002) recommended protected buffer zones of 10 km around roosts between April 1 and October 31, particularly if a site supports maternity roosting in pinyon-juniper or subalpine conifer habitats where foraging takes place near the roost. They also recommended that within that zone, timber harvest should be minimized from April through October and fire suppression should be vigorously pursued year-round. No burning or other vegetation management should occur within a 2.5 km radius of known roosts to conserve foraging habitat. If vegetation management is necessary, Pierson et al. (1999) recommended against affecting more than one-half of a 2.4 km radius buffer around a roost site in a given decade. Without site-specific occupancy data, these guidelines should err on the side of conservation and be applied to sites with apparent roost potential.

  The Nevada and Colorado Bat Management Plans (Altenbach 2002, Ellison et al. 2004) suggested contacting climbing organizations, commercial guides, and caving clubs to disperse environmental educational information concerning bats and the effects these recreational activities may have on bat populations. Land management agencies may wish to consider instituting a permit system to regulate rock climbing in potential habitat, and prohibit climbing in locations known or highly suspected to have spotted bat roosts.

  Although these guidelines specifically address vegetation treatment and certain recreational activity, the buffer concept should be considered where other potentially harmful activities are considered. The size and nature of buffer restrictions can be tailored to the activity and its potential for harmful effects.

- **Limit Scientific Collection/Human Impacts:** All bat research activities must be conducted responsibly and with the best interest of the bat population in mind. Several researchers have identified the potential for uncontrolled collection of museum specimens to cause significant impacts on spotted bat populations (see Extrinsic Threats section above). State wildlife agencies issue collection permits for native species and should be encouraged to severely restrict the legal collection of spotted bats. State scientific research and collection permits should contain stringent requirements for protection of the bat resource during research projects. Collection of members of this species should be allowed only where justified for its management/protection, not merely to add to museum collections. Individual state bat management plans in Colorado and Wyoming address this topic. Land management agencies should cooperate with the states to restrict collection on public lands.

- **Protection of foraging areas:** Spotted bat occupancy of an area is based on the presence of rock-faced cliff roosting habitat, probably within 40 km of foraging areas. Potentially important foraging habitats within such zones, as discussed earlier in this document, should receive special management consideration to maximize its habitat potential. Vegetation that supports the community of insects must be retained in optimal condition to maintain habitat value. Large-scale vegetation conversions or modifications should be evaluated for negative impacts to spotted bats during project planning. Pinyon-juniper and ponderosa pine, both valuable foraging and roosting habitat for this species, must be managed to retain habitat potential. Management should seek to maintain forested openings in a configuration that mimics the natural condition, and a mixed forest structure of second-growth and mature stands, since this combination creates preferred habitat for bats. Pinyon-juniper management should ensure that a significant percentage of forest canopy be maintained in each watershed (percentage depends on local conditions and understanding of historical conditions, where available).

Timber harvest and other human-created forest openings can be planned to enhance bat foraging habitat by retaining natural, pre-harvest variability in stand structure and natural dispersion of openings of varied size and shape. Regeneration openings may provide foraging areas and, in general, stand level changes that result in more open habitat may benefit spotted bats (Schmidt 2002). Variation in harvest rotation ages, cutblock sizes, and cutblock residuals (green trees, snags, downed woody material) should approximate natural fire return intervals, fire sizes, and post-fire residuals. Modified type-cut logging strategies can help create a forest mosaic similar to pre-harvest (Walker et al. 1995).

❖ **Protection of water resources:** Open water sources of proper configuration that are aerially accessible to bats (unobstructed by man-made features such as fences or natural features such as trees or other vegetation) are necessary for bats to drink on the wing. Wet areas around ponds, seeps, wet meadows, and springs support the insects upon which bats forage. Land management activities that alter bodies of water, water regimes, or water quality may impact bats and should be carefully evaluated. Such activities may include altering wetlands or ponds; livestock grazing that alters vegetative cover and composition, altering hydrology; water diversions for irrigation or municipal use; timber harvest that impacts snow accumulation patterns, alters hydrology, or changes meadow microclimates; or contamination of water sources from mineral or fossil fuel operations, or the application of pesticides.

Water sources used by bats, especially those in riparian zones in desert ecosystems, must be managed to retain native vegetation and water regimes. Pierson et al. (1999) and Ellison et al. (2004) recommended that at a minimum wetlands within 16 km of bat roosts be managed to retain year-round open water and natural vegetative structure. Management includes maintaining healthy riparian vegetation, large woody materials in lakes and ponds, and natural stream and wetland hydrology and geomorphology. Livestock grazing of mountain meadows, spring areas, and riparian zones should be managed to retain native vegetation, natural hydrological regimes, and water quality, in order to retain habitat of prey species and quality sources of open water for drinking.

Establishment and maintenance of water sources such as wildlife or livestock/wildlife tanks near suitable foraging or roost sites will benefit spotted bats (Mollhagen and Bogan 1997). Suggested specifications for water sources have recently been published by Bat Conservation International (Taylor and Tuttle 2007). This information and the authors' personal experience suggest tanks and ponds should be at least 2.4 m in diameter, or have a 2.4 m run, and be at least 0.5 m deep in order to benefit spotted bats. Excluding livestock from the primary water source to maintain clean, clear water is recommended, as long as fencing does not restrict aerial access by bats. To insure clean water and bat access, fences should be placed entirely around the water source and at least 30 m from the water with the top wire less than about 1 m high. Water can then be piped to an off-site watering trough for livestock. Also, tanks should incorporate structures that allow bats falling into them to escape. Escape structures should extend into the water and meet the inside wall of the tank, reach to the bottom of the tank to accommodate fluctuating water levels, be firmly secured to the tank's rim, be made of grippable, long-lasting materials, and have a slope no steeper than 45 degrees. More details on acceptable water tank configurations for bats can be found in Taylor and Tuttle (2007).

No livestock- or wildlife-excluding structures should be placed over the tank itself. Trees, shrubs, and other vegetation within the fenced area should be managed to keep it low enough to allow bats on-the-wing access to the water. Maintain vegetation within 6 m of the water at less than 15 cm in height, grading upward in height to no more than 1.05 m at the fence. Pregnant females may be less maneuverable and rely heavily on unobstructed in-flight access to water sources, such as tanks and ponds during the spring-early summer period (May-June). Consequently, every attempt should be made to maintain accessible water during that time period. Access to water is also critical for lactating female bats (Kurta et al. 1989, Schmidt 1999), which may include the period June through August. Bats can access water in caves, so presumably they could use manmade guzzlers if there is sufficient room to maneuver in-flight (Schmidt 1999).

Land management agencies should consider reconstruction of existing tanks and ponds to meet bat needs, and schedule regular maintenance of fences, tanks, and vegetation at water sources to retain optimal bat habitat values. Impacts to water resources and riparian habitats from livestock grazing and human recreation could be partially mitigated by managing a percentage of those habitats with a primary emphasis on native wildlife, with designated areas having neither livestock grazing nor human recreation uses that are detrimental to springs, ponds, seeps, and meadows.

- **Elimination of exposure to toxic chemicals:** Bats should be physically excluded from oil reserve pits, cyanide ponds, and wastewater facilities that contain toxic chemicals. Currently, there are no open cyanide ponds in either Wyoming or Colorado. Furthermore, Colorado requires bats to be excluded from cyanide ponds if the ponds contain more than 40 parts per million of cyanide. Active mines are regulated in Colorado to prevent releases of acid mine drainage to surface or groundwater. Mining companies in Colorado are required to "describe measures to prevent wildlife from coming into contact with designated chemicals, toxic or acid forming chemicals, or areas with acid mine drainage" (mineral rules and regulations of the Colorado Mined Land Reclamation Board (2 CCR 407-1, Rule 6.4.20 (18). Lee and Jones-Lee (2002) suggests that wetlands with sediment containing compounds such as DDT and DDE that might be bioaccumulated at higher trophic levels should come under the jurisdiction of Environmental Protection Agency guidelines (http://www.epa.gov/superfund/health/conmedia/sediment/guidance.htm). Where practicable, it appears prudent to exclude bats from such sites until further chemical exposure is unlikely. Where large areas are impacted, such as riverine systems down-gradient from historic mining areas, large-scale remediation may be the only option to prevent bioaccumulation of hazardous substances by bats and other wildlife.

State and federal wildlife authorities should thoroughly investigate insecticide spraying projects before they are allowed in areas used by spotted bats. Large-scale pesticide application projects to control forest moths, Mormon crickets, or other insect species perceived to be economic pests should include pre-project identification of bat roosting, watering, and foraging areas within and near proposed application areas. Ideally, these areas would be avoided entirely. If that cannot be accomplished, management to favor bats should include using small spray blocks to minimize mortality of non-target insects, to confine impacts to highly localized sites, and to minimize drift (Ellison et al. 2004). A 3.2 km buffer should be placed around roosts and adjacent riparian areas and meadows to avoid direct poisoning of bats. Application should occur only in daylight hours to avoid foraging periods (early evening and early morning). It should also be fundamental that pesticides are selected carefully to minimize the potential of secondary poisoning of bats and non-target effects on bat food species.

Pre- and post-project insect population monitoring is recommended for spraying projects conducted in areas occupied by spotted bats to document impacts to non-target insect populations that comprise a substantial portion of the diet. If significant impacts are documented, alternative control programs should be considered for the future.

Survey, inventory, and monitoring

Effective management begins with adequate inventory, and both inventory and management of spotted bats should be pursued at a multiple geographic scales. Areas of potentially suitable habitat may be identified from GAP land use/land cover maps, or other GIS-level mapping. Areas identified with potentially suitable habitat characteristics should then be surveyed for actual presence of the species. Where presence is confirmed, roosting, water, and foraging habitats used by local populations should be identified and mapped.

Long-term monitoring is needed at priority sites, with special emphasis on riparian habitats and water sources, the most common and most vulnerable of the habitats required by this species. At such sites, intensive annual surveys of selected subpopulations should be considered until population size and the extent of the landscape used are known.

Inventory: Methods for intensive field inventory and monitoring of bats are presented in a number of publications (e.g., Ruffner et al. 1979, Navo et al. 1992, Storz 1995, Cockrum et al. 1996, Priday and Laurion 1998, Rabe 1998, Priday and Luce 1999). Mist-netting or acoustic surveys over open water ponds where bats drink, and in foraging areas around water sources, are sometimes effective for capturing spotted bats or recording audible signatures to document its presence. This species is one of the few U.S. bats with an echolocation call audible to the human ear, 8 to 15 kHz (Navo et al. 1992). Therefore, audible surveys are a very useful survey method unavailable for other bat species in Wyoming and Colorado (except the big free-tailed bat).

Because the spotted bat is not active in cold weather, inventory and survey efforts will be most effective between June and August in both Wyoming and Colorado. At lower elevations and latitudes, the survey period may extend 2 to 4 weeks before and after those dates. Sampling must, at a minimum, be conducted from dusk until 3 hours after dusk and from 3 hours before dawn until dawn (Priday and Luce 1999). However, by sampling all night a more accurate picture of activity patterns and how they change seasonally will emerge. Phenomena such as reported by Rodhouse et al. (2005), who observed two spotted bats flying together 4 hours after sunset and recorded no other passes at that site during five additional nights of listening and mist netting can be expected. Bat activity may vary depending upon external factors such as temperature, precipitation, wind, and cloud cover. A brief review of methods follows:

1. Observers should be familiar with spotted bat calls before beginning the field project and be aware that there can be a large variation in daily and seasonal bat activity. Therefore, several nights of survey effort at a given site will likely be necessary to determine presence/absence (Priday and Laurion 1998, Priday and Luce 1998, 1999). Sites should be visited for two nights consecutively if the surveyor believes bat activity is normal, and three nights if weather or other factors negatively impact survey conditions. Listening posts should be within hearing range of canyons containing cracks and fissures, high, bare rock walls, and rock ridges. The observer should constantly listen for audible calls throughout the survey period.

2. The spotted bat can be effectively inventoried or surveyed using acoustic systems such as ANABAT® (http://www.titley.com.au/tanabat.htm) and Peterson Sonobat® (http://www.batsound.com/; http://www.sonobat.com/). Since these systems differ in capabilities and require a considerable amount of time investment and training for both initial use and maintaining proficiency, we suggest that potential users consult any of the following: Lance et al. (1996), Hayes (1997), O'Farrell (1997), Barclay (1999), Britzke et al. (1999), Corben and Fellers (2001) or other sources of information before contemplating use of either system. Land managers may find it more cost- and time-effective to contract inventories or surveys, rather than purchase the equipment and acquire the necessary training. Acoustic monitoring will be most effective when combined with audible surveys or mist-netting when first attempting to establish presence/absence in a new area.

3. Although presence of spotted bats may be verified using standard mist-netting techniques, alone it cannot be relied upon

to declare absence in a given area since this species is infrequently captured using conventional mist netting techniques (Priday and Luce 1999, Rodhouse et al. 2005). If spotted bat presence has been verified by audible or acoustic surveys, mist-netting may be useful to determining sex, breeding condition, and age of bats (adult versus juvenile). However, unless conditions are ideal the capture rates are likely to be low and not afford a representative sample of the population. As with other bats, spotted bats are most easily captured at watering sites, because they must descend to water level to drink on the fly. Livestock watering tanks, streams with quiet pools, seeps with open water, and open-water wetlands are excellent places to capture bats. Isolated surface water sources are more likely to concentrate bats than areas with many water sources and the best locations at which to focus mist-netting efforts. Spotted bats are very difficult to capture when foraging, because they generally fly high above vegetation (Rodhouse et al. 2005) and in unpredictable patterns.

Monitoring: After potential habitat and local populations are identified and inventoried, monitoring should be conducted at regular intervals of 1 to 3 years. Monitoring at roost sites is a common method used for most bat species. However, due to the remoteness of spotted bat roosts, and apparent solitary roosting at maternity sites and hibernacula, this method is not effective for this species (Rabe et al. 1998, Priday and Luce 1999). Therefore, monitoring in Wyoming and Colorado using acoustic surveys at known foraging and watering sites between June and August is the preferred approach.

For monitoring across a state, Altenbach (2002) recommended using a 100 km grid system to select at least 60 wetlands for annual monitoring of the general bat population, including spotted bats. This method involves a stratified random sample in various habitat types and elevation zones. It requires that a statistically valid number of sites in a given state fall within spotted bat habitat and contain a local population. Under these conditions this may be the most effective broad-scale monitoring method so far suggested for this species.

The authors recommend that a similar monitoring system be devised for lands administered by federal land management agencies. The number of sample sites on a given planning area would depend upon the number of areas with potential habitat. If the number of areas is low, we recommend that sampling occur at every potential or occupied site at 1 to 3 year intervals versus sampling only at a random subset of locations.

Targeted areas in Region 2

From both a range-wide and Region 2 perspective, it appears that much spotted bat research to date has been conducted on national forests, lands administered by the BLM, national parks and monuments, and state parks. In Wyoming, the 14 documented locations of spotted bats are all on or adjacent to large blocks of public land, including lands administered by the BLM, Bighorn Canyon National Recreation Area, Flaming Gorge National Recreation Area, and Boysen State Park (Priday and Luce 1998). Some Colorado records are from private land in western Colorado, but most observations are from BLM-administered lands, Mesa Verde National Park, Dinosaur National Monument, and Black Canyon of the Gunnison National Park (K. Navo personal communication 2005). Although publicly owned, these areas are not necessarily managed to retain optimal habitat for bats; therefore, developing management strategies to conserve bat habitat is needed and may be crucial to the welfare of regional populations of spotted bats.

Information Needs

Based on only a few records, general distribution of the spotted bat is known for the Bighorn Basin in north-central Wyoming. Recent records in southwestern and central Wyoming indicate that additional work is needed to identify potential habitat and to delineate local populations. Further, since Wyoming may include habitats at the upper altitudinal range of this species, the distribution and structure of Wyoming populations may differ from those in other states, where the bulk of reported research has occurred. Understanding these differences may contribute to range-wide management of the spotted bat.

The Colorado Bat Conservation Plan (Ellison et al. 2004) contains a detailed list of research needs for Colorado, a summarization of which follows:

1. Surveys
    - ❖ identify and map potential spotted bat habitat in Colorado and Wyoming
    - ❖ where potentially suitable habitat exists, conduct surveys using standardized protocols to determine presence/absence of the species

- ❖ determine the winter status of spotted bats in Wyoming and Colorado
- ❖ develop and improve remote survey techniques, including infrared photography, acoustic techniques, and electronic roost monitoring

2. Local roosting habitat identification and management
   - ❖ identify potential suitable roosting habitat in Region 2 using GIS techniques
   - ❖ define characteristics of suitable cliff-roosting habitat for spotted bats
   - ❖ determine the level and nature of human disturbance that results in roost abandonment, how or if alternate roosts are selected, and whether reproductive success is lowered as a result of disturbance
   - ❖ increase surveys of human structures to increase understanding of the use and importance of these structures as roost sites
   - ❖ evaluate how the availability of human-made structures used as roost sites affects landscape scale management in diverse natural habitat settings

3. Water resources
   - ❖ identify water sources that could, with modification, be used by bats
   - ❖ develop techniques that will make such sources effective for bat use
   - ❖ develop effective designs for guzzlers that allow easy access by bats
   - ❖ determine whether the presence of open water all year is critical for occurrence of spotted bats, or if open water is necessary only during lactation.

4. Movements
   - ❖ define seasonal movement patterns of spotted bats, particularly in higher elevation ranges in Region 2
   - ❖ determine the home range of known sub-populations

5. Forest/Riparian Habitat Management
   - ❖ investigate the importance of riparian habitats for production of preferred spotted bat prey
   - ❖ conduct research into the use of post-fire habitats

6. Potential Impacts of Land Management Practices
   - ❖ obtain more information on the effects of timber management practices on spotted bat habitat (e.g., size, configuration, juxtaposition of openings)
   - ❖ document the impact of insect control projects on insect populations in spotted bat habitat (e.g., if/how are bats being exposed to chemicals, how bats are impacted by reduction of insect prey base)
   - ❖ obtain data on the impact of rangeland conversion projects on spotted bat foraging habitat
   - ❖ evaluate the effects of logging, grazing, fire suppression, energy extraction, pesticide application, and scientific collection on species distribution, habitat use, and reproductive success
   - ❖ determine a level of "take" due to scientific collection and study methods to avoid adverse population-level impacts, especially to pregnant and lactating females

7. Metapopulation Structure
   - ❖ more data are needed on metapopulation structure in spotted bats and the interrelationships of subpopulations (i.e., how does recolonization occur following extinction events)

8. Landscape Scale Management
   - ❖ identify ecosystem and habitat components that combine to provide suitable habitat for each known sub-population
   - ❖ examine habitat dispersion patterns that provide for effective spotted bat habitat connectivity and population interchange

9. Reproduction Information
   - ❖ examine basic biology/life history of spotted bats, particularly reproduction, to more effectively manage the species and to predict how human presence or habitat alteration affect key attributes in primary and peripheral habitats

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APPENDIX

Matrix Life Cycle Model of Spotted Bat Prepared for USDA Forest Service, Region 2

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December 2003

The life history described in this assessment provided the basis for a nine-stage life cycle graph (**Figure A1**) and matrix population analysis, for a birth-pulse population with a one-year census interval and a post-breeding census (Cochran and Ellner 1992, McDonald and Caswell 1993, Caswell 2000) for spotted bat. The model has two kinds of input terms: P_i describing survival rates, and m_i describing fertilities (**Table A1**). **Figure A2a** shows the symbolic terms in the projection matrix corresponding to the life cycle graph. **Figure A2b** gives the corresponding numeric values. The model assumes female demographic dominance so that, for example, fertilities are given as female offspring per female; thus, the offspring number used was half the litter size, assuming a 1:1 sex ratio. Note also that the fertility terms (F_i) in the top row of the matrix include both a term for fledgling production (m_i) and a term for the survival of the mother (P_i) from the census (just after the breeding season) to the next birth pulse almost a year later. Lambda (λ), the population growth rate, was 1.003 based on the estimated vital rates used for the matrix. Although this suggests a stationary population, the value is subject to the many assumptions used to derive the transitions and should not be interpreted as an indication of the general well-being and stability of the population. Other parts of the analysis provide a better guide for assessment.

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. Sensitivity is the effect on population growth rate (λ) of an absolute change in the vital rates (a_{ij}, the arcs in the life cycle graph [**Figure A1**] and the cells in the matrix, A [**Figure A2**]). Sensitivity analysis provides several kinds of useful information (see Caswell 2001, pp. 206-225). First, sensitivities show how important a given vital rate is to population growth rate (λ), which Caswell (2001, pp. 280-298) has shown to be a useful integrative measure of overall fitness. One can use sensitivities to assess the relative importance of survival (P_i) and fertility (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity of data, but could also result from use of inappropriate estimation techniques or other errors of analysis. To improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing the population growth (λ) of endangered species or the "weak links" in the life cycle of a pest.

Figure A3 shows the "possible sensitivities only" matrix for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible – for example, the sensitivity of λ to moving from

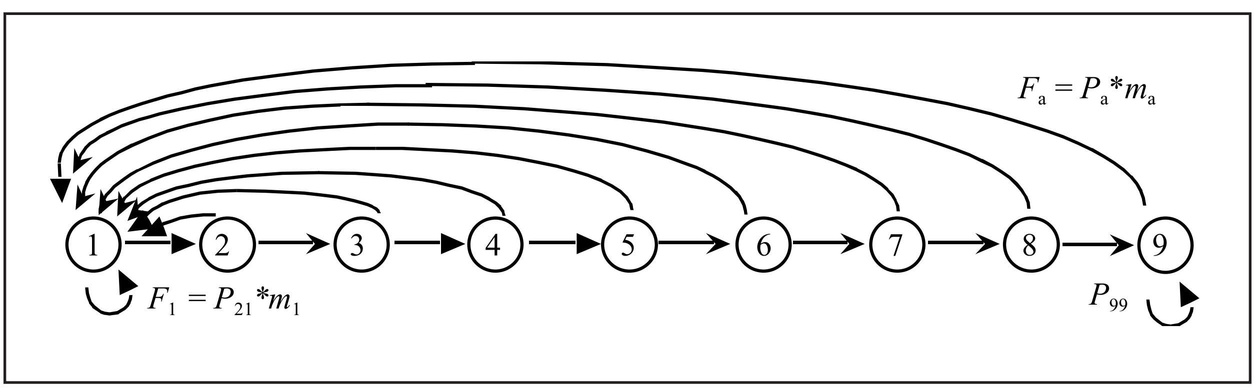

Figure A1. Life cycle graph for spotted bat, consisting of *nodes*, describing stages in the life cycle and *arcs*, describing the *vital rates* (transitions between stages). The horizontal arcs are "adult" survival transitions (P_a = 0.875). The self-loop from Node 1 to itself describes fertility of first-year females. The self-loop on Node 9 describes survival of the oldest stage. The remaining arcs describe fertility of "adult" females ($F_a = P_a * m_a$). Stages 1 to 8 are age-specific (first-year, second-year etc.), while the final node is a mixed-age stage.

Table A1. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrix for spotted bats.

Parameter	Numeric value	Interpretation
m_1	0.3	Number of female offspring produced by a first-year female
m_a	0.5	Number of female offspring produced by an "adult" female
P_{21}	0.27	First-year survival rate
P_a	0.875	Annual survival rate of "adult" females

Stage	1	2	3	4	5	6	7	8	9
1	$P_{21} * m_1$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$	$P_a * m_a$
2	P_{21}								
3		P_a							
4			P_a						
5				P_a					
6					P_a				
7						P_a			
8							P_a		
9								P_a	P_a

Stage	0.6	2	3	4	5	6	7	8	9
1	0.081	0.4375	0.4375	0.4375	0.4375	0.4375	0.4375	0.4375	0.4375
2	0.27								
3		0.875							
4			0.875						
5				0.875					
6					0.875				
7						0.875			
8							0.875		
9								0.875	0.875

Figure A2. The input matrix of vital rates, A (with cells a_{ij}) corresponding to the spotted bat life cycle graph (**Figure A1**). a) Symbolic values. b) Numeric values. Note that survival (P_a) and offspring production (m_a) are age-independent after the first year.

Stage	1	2	3	4	5	6	7	8	9
1	0.122	0.033	0.029	0.025	0.022	0.019	0.017	0.014	0.099
2	0.417								
3		0.112							
4			0.098						
5				0.085					
6					0.074				
7						0.065			
8							0.057		
9								0.049	0.337

Figure A3. Possible sensitivities only matrix, S_p (remainder of matrix is zeros). The three transitions to which λ of spotted bats is most sensitive are highlighted: first-year survival (Cell s_{21} = 0.417), survival of the mixed-age stage of oldest individuals (Cell s_{99} = 0.337), and first-year fertility (Cell s_{11} = 0.122).

Age Class 3 to Age Class 2). In general, changes that affect one type of age class or stage will also affect all similar age classes or stages. For example, any factor that changes the annual survival rate of Age-class 3 females is very likely to cause similar changes in the survival rates of other "adult" reproductive females (those in Age-classes 4 through 7). It is, therefore, usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For this model, the result is that the sensitivity of λ to changes in first-year survival (0.417; 25 percent of total) is considerably larger than to changes in other rates. The summed sensitivities of λ to changes in "adult" survival rates was 0.877 (52 percent of the total sensitivity). The Spotted bat shows little sensitivity to changes in fertility (the first row of the matrix in **Figure A3**, 23 percent of total). The major conclusion from the sensitivity analysis is that enhancement of survival is the key to population viability.

Elasticity analysis

Elasticities are the sensitivities of λ to proportional changes in the vital rates (a_{ij}) and thus partly avoid the problem of differences in units of measurement (for example, we might reasonably equate changes in survival rates or fertilities of 1 percent). The elasticities have the useful property of summing to 1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original vital rates (the a_{ij} arc coefficients on the graph or cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction (F_i) and survival (P_i) for a given species. It is important to note that elasticity as well as sensitivity analysis assumes that the magnitude of changes (perturbations) to the vital rates is small. Large changes require a reformulated matrix and re-analysis.

Elasticities for spotted bats are shown in **Figure A4**. The λ of spotted bats was most elastic to changes in first-year survival, followed successively by survival at subsequent ages. Overall, survival transitions accounted for approximately 88 percent of the total elasticity of λ to changes in the vital rates. The survival rates are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Other demographic parameters

The stable stage distribution (SSD, **Table A2**) describes the proportion of each Stage (or Age-class) in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable age distribution, regardless of whether the population is declining, stationary or increasing. Under most conditions, populations not at equilibrium will converge to the SAD within 20 to 100 census intervals. For spotted bats at the time of the post-breeding annual census (just after the end of the breeding season), young of the year represent 32 percent of the population, with the oldest adults representing 26 percent of the population. Reproductive values (**Table A3**) can be thought of as describing the "value" of a stage as a seed for population growth relative to that of the first stage (newborn or, in this case, egg). The reproductive value of the first stage is always 1.0. A female individual in any of the "adult" stages is "worth" 3.4 female young of the year (Caswell 2001). The reproductive value is calculated as a weighted sum

Stage	1	2	3	4	5	6	7	8	9
1	0.01	0.014	0.013	0.011	0.01	0.008	0.007	0.006	0.043
2	0.112								
3		0.098							
4			0.085						
5				0.074					
6					0.065				
7						0.057			
8							0.049		
9								0.043	0.294

Figure A4. Elasticity matrix, E (remainder of matrix is zeros). The λ of spotted bats is most elastic to changes in survival of the mixed-age stage of oldest individuals (Cell e_{99} = 0.294), followed fairly distantly by first-year (Cell e_{21} = 0.112) and second-year survival (Cell e_{32} = 0.098).

Table A2. Stable stage distribution (SSD, right eigenvector). At the census, 32 percent of the population should be young of the year. Approximately 26 percent will be a mixed-age group of the oldest females. The remaining 42 percent will be adults in their second to eighth year of life.

Stage	Description	Proportion
1	First-year females	0.322
2	Second-year females	0.087
3	Third-year females	0.076
4	Fourth-year females	0.066
5	Fifth-year females	0.057
6	Sixth-year females	0.050
7	Seventh-year females	0.044
8	Eighth-year females	0.038
9	Oldest females	0.261

Table A3. Reproductive values for females. Reproductive values can be thought of as describing the "value" of a stage as a seed for population growth, relative to that of the first (newborn) stage, which is always defined to have the value 1.0.

Stage	Description	Reproductive values
1	First-year females	1.000
2	Second-year females	3.415
3	Third-year females	3.415
4	Fourth-year females	3.415
5	Fifth-year females	3.415
6	Sixth-year females	3.415
7	Seventh-year females	3.415
8	Eighth-year females	3.415
9	Oldest females	3.415

of the present and future reproductive output of a stage discounted by the probability of surviving (Williams 1966). The cohort generation time for spotted bats is 8.4 years (SD = 7.5 years).

Stochastic model

We conducted a stochastic matrix analysis for spotted bats. We incorporated stochasticity in several ways, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (**Table A4**). Under Variant 1 we altered the fertilities (F_i). Under Variants 2 and 3 we varied the survival at all ages (P_i). Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the Stable Stage Distribution (SSD) under the deterministic model. Beginning at the SSD helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We varied the amount of fluctuation by varying the standard deviation of the random normal distribution from which the stochastic vital rates were selected. The default value was a standard deviation of one quarter of the "mean" (with this "mean" set at the value of the original matrix entry [vital rate], a_{ij} under the deterministic analysis). Variant 3 affected the same transitions as Variant 2 (P_i) but was subjected to lesser variability (SD was 1/8 rather than 1/4 [= 0.125 compared to 0.25] of the mean). We calculated the stochastic growth rate, $\log\lambda_s$, according to Eqn. 14.61 of Caswell (2000), after discarding the first 1,000 cycles in order to further avoid transient dynamics.

The stochastic model (**Table A4**) produced two major results. First, altering the survival rates had a much more dramatic effect on λ than did altering the fertilities. For example, the median ending size under the varied fertilities of Variant 1 (3.9×10^6) greatly increased from the starting size of 10,000. In contrast, the same degree of variation acting on survival under Variant 2 resulted in a median ending size of only 776. Varying the survival rates with a smaller range of fluctuation (SD = 1/8 rather than 1/4) under Variant 3 resulted in an increase similar to that under

Table A4. Summary of three variants of stochastic projections for spotted bats. Each variant consisted of 100 runs, each of which ran for 2,000 annual census intervals.

	Variant 1	Variant 2	Variant 3
Input factors:			
Affected cells	F_i	P_i	P_i
S.D. of random normal distribution	1/4	1/4	1/8
Output values:			
Deterministic λ	1.003	1.003	1.003
# Extinctions / 100 trials	0	31	0
Mean extinction time	???	1,386	???
# Declines / # survived populations	0/100	52/69	4/100
Mean ending population size	4.5 X 10^6	120,673	1.1 X 10^7
Standard deviation	2.6 X 10^6	505,577	5.6 X 10^7
Median ending population size	3.9 X 10^6	776	1.0 X 10^6
Log λ_s	0.003	-0.003	0.002
λ_s	1.003	0.997	1.002
% reduction in λ	0.011	0.577	0.095

the fertility variant (1.0 X 10^6). This difference in the effects of stochastic variation is predictable from the sensitivities and elasticities. λ was much more sensitive to changes in first-year survival, P_{21}, than it was to changes in the entire set of fertilities, F_i. Second, large-effect stochasticity has a negative effect on population dynamics, at least when it impacts transitions to which λ is highly sensitive. The negative effect of stochasticity occurs despite the fact that the average vital rates remain the same as under the deterministic model – the random selections are from a symmetrical distribution. This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2000). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization will therefore be most likely to end at a population size considerably lower than the initial population size. For spotted bats under the survival Variant 2, 31 out of 100 trials of stochastic projection went to extinction, with a further 52 populations declining in size. In contrast, under the fertilities Variant 1 no populations went extinct and none declined. Variant 3 shows that the magnitude of fluctuation has a potentially large impact on the detrimental effects of stochasticity. Decreasing the magnitude of fluctuation decreased the severity of the negative impacts – the number of extinctions went from 31 to 0, with only four of the 100 replicate populations declining. These results suggest that populations of spotted bats are relatively tolerant to stochastic fluctuations in offspring production (due, for example, to annual climatic change or to human disturbance) but extremely vulnerable to variations in the survival of adult stages. Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive transitions in their life cycles. A possible concern is that anthropogenic impacts may induce variation in previously invariant vital rates (such as annual adult survival), with consequent detrimental effects on population dynamics. Further, in the case of high sensitivity of λ to changes in first-year survival, selection may be relatively ineffective in reducing variability that surely results from a host of biotic and abiotic factors.

Potential refinements of the models

Clearly, the better the data on survival rates, the more accurate the resulting analysis. Data from natural populations on the range of variability in the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of "stochastic" matrices that mirrored actual variation. One advantage of such a series would be the incorporation of observed correlations between variations in vital rates. Using observed correlations would incorporate forces that we did not consider. Those forces may drive greater positive or negative correlation among life history traits. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.

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